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SPATIAL CONCEPTS OF ELEMENTARY SCHOOL CHILDREN

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "Spatial Concepts of Elementary School Children" by John Orchard Towler in partial fulfilment of the requirements for the degree of Master of Education.

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ABSTRACT

The purpose of this study was to select four spatial concepts which the investigator considered to be necessary to map reading and map interpretation and to examine their development in elementary school children. The four concepts chosen for investigation were:

1. the concept of a reference system,
2. the concept of distance,
3. the concept of direction, and
4. the concept of scale.

In addition, the study sought to clarify the relationships between the development of these concepts and sex, socio-economic status, chronological age, intelligence and grade level.

A battery of five subtests, each designed to measure a particular concept, was constructed and administered individually to a sample of one hundred and twenty elementary school children in grades one to six inclusive. The sample consisted of twenty pupils from each grade level and each sex was equally represented. These children ranged in age from approximately six year to twelve years. All of the subjects were enrolled in the Public School System in the city of Edmonton, Alberta, Canada when the testing program was carried out in May and June, 1965.

A summary of the subjects' performance on each of the various subtests was compiled and an effort was made to determine the stages

of conceptual development which led to the acquisition of the four concepts under investigation. Statistical analysis was applied to the subjects' scores in an attempt to clarify the relationships noted earlier.

The most important findings of this study were as follows:

1. The general pattern of ontogenetic development of spatial concepts as described by Jean Piaget was observed, however, there were certain discrepancies. The development of the concepts of a general reference system and scale occurred later for this sample, while the development of the concept of direction appeared to follow the logical development of thought processes as described by Piaget.

2. Sex and socio-economic status were not significantly correlated with the development of any of the spatial concepts under investigation.

3. Chronological age and grade level were signficantly correlated with the development of each of the four concepts being investigated.

4. Intelligence for this sample was significantly correlated with the development of the concepts of a reference system, direction and scale but not distance.

Some implications for educational practice are presented with suggestions for further research.

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CHAPTER I

THE PROBLEM, ITS NATURE AND SIGNIFICANCE

I. INTRODUCTION

The study of the formation of children's concepts is of the utmost importance to educators. Until we can find out how children think and what processes they go through in developing certain concepts it is exceedingly difficult, if not impossible, to design programs of studies involving learning sequences which will adequately fit the needs of children at various stages of conceptual development. Consequently, there is an increasing interest in the study of children's thought processes and the manner in which they acquire certain concepts. Perhaps the greatest quantity of work in this field has been conducted by the Swiss psychologist, Jean Piaget, who has investigated the growth of children's concepts in a variety of areas. One of these areas, that of the child's conception of space, has particular relevance to several learning experiences inherent in a number of school subjects. The degree to which the child has developed his conception of space has a direct bearing on both his ability to comprehend certain natural phenomena and his ability or readiness to acquire a deeper

understanding of such phenomena. If, for example, a child cannot distinguish between an object and reflection or mirror image of the object this inability would have important consequences in terms of the child's perception and comprehension of letters, numbers, words, geometric figures, and all spatial configurations. In terms of school subjects then, the child's development of a concept of space would affect his performance in such subjects as reading, writing, art, arithmetic, map work and perhaps others.

For the purposes of this study, four concepts involved in the child's total conception of space have been selected for investigation and will be examined in terms of their effect on the child's ability to read and interpret maps.

II. THE PROBLEM

Many map study programs have been devised containing a sequence of learnings which children at certain grade levels are assumed to be capable of acquiring. (However, few if any of these programs have been based on sound research evidence regarding the child's level of development of those concepts which could be considered fundamental to the understanding of the skills to be developed.) It is the purpose of this study to select four concepts which the investigator considers to be necessary to map reading and map interpretation and to examine their development

in elementary school children. The four concepts chosen for examination are:

1. the concept of a reference system,
2. the concept of distance,
3. the concept of direction,
4. the concept of scale.

These particular concepts are considered to be interrelated and fundamental to map reading and map interpretation for these reasons: unless a child has the concept of a reference system or frame of references, one object or point on a map cannot be established relative to another object or point. Once a reference system is established, the location of any point or object may be expressed in terms of its distance and direction from another point or object. An understanding of the concept of scale is also important since the relative distance between objects changes according to the scale being used on a map.

The development of children's conception of a reference system will be examined using a method suggested by the work of Piaget. According to Piaget, "the simplest and most natural reference frame available to the child is probably that provided by the physical world in the shape of vertical and horizontal axes..."[1] Once the child has discovered the existence of these

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[1] Jean Piaget and Barbel Inhelder, The Child's Conception of Space, (London: Routledge and Kegan Paul, 1963), p. 379.

two axes, he can then combine them into a comprehensive system of coordinates. Following this, a coordinate axis system or grid system can be utilzed by the child to locate objects which in turn may be used as reference points for other objects.

In examining the development of this concept, Piaget found that it followed a sequential development terminating in Piaget's terms, at the stage of formal operations or between the ages of eleven to thirteen. In the course of his investigations Piaget studied the child's ability to use a system of references as represented by vertical and horizontal lines, and a natural reference system represented by the interesection of a path and a stream on a diagrammatic model of a landscape. This study is a partial replication of some of the aspects of Piaget's work and will be used to examine children's ability to use both a natural and an artificial reference system.

The necessity of a basic understanding of the concepts of direction and distance cannot be disregarded if a child is to locate points accurately on a map. As the cartographer, Arthur Robinson, states,

> In order to locate points on any surface it is necessary to have concepts and definitions of direction and distance. All spatial locations are relative, and they must, therefore, be established in relation to some reference or starting point. If such a point is designated, then the location of every other point on the surface can be stated in terms of a defined direction and distance from it.[2]

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[2]Arthur H. Robinson, Elements of Cartography, (New York: John Wiley and Sons Inc., 1960), p. 18.

In addition to the concepts of a reference system, distance and direction, the concept of scale must also be developed before the child can fully understand spatial orientations as represented on a map. Until the latter is developed, a child cannot understand the necessity of altering the distance between two objects relative to the scale of the map on which they are shown.

The Null Hypotheses

The four concepts will be studied with a view to determining their relationship with such factors as: sex, socio-economic status, chronological age, intelligence, and grade level in children from grades one to six. Hence, the following hypotheses will be tested:

1. There is no significant correlation between sex and the development of concepts of a reference system, distance, direction, and scale.

2. There is no significant correlation between socio-economic status and the development of concepts of a reference system, distance, direction, and scale.

3. There is no significant correlation between chronological age and the development of concepts of a reference system, distance, direction, and scale.

4. There is no significant correlation between intelligence and the development of concepts of a reference system, distance, direction, and scale.

5. There is no significant correlation between grade level and the development of concepts of a reference system, distance, direction, and scale.

III. LIMITATIONS

No interpretation of the findings of this study should be made without consideration being given to the following limitations. It must be clearly understood that this study is based on one fundamental assumption, namely, that the test items are valid measures of the concepts under investigation and that a subject's performance on an item is indicative of his or her acquisition of the particular concept that item was designed to measure. A further limitation is that there may well be other concepts basic to a child's understanding and interpretation of maps. This study, however, will be confined to an investigation of the development of four concepts only. A third limitation is that this investigation will be confined to a sample of urban pupils in grades one to six inclusive. No attempt will be made to account for any effect that previous instruction in map work may have on a child's performance on the test items. Similarly, no attempt will be made to determine and take account of the left or right dominance of the subjects. This would apply specifically to the test items involving directions.

IV. THE SIGNIFICANCE OF THE STUDY

One of the purposes of social studies programs (of which geography is an element) is to teach children how to read and interpret maps. However, these are two separate and distinctly different abilities, one dependent upon the other. Before a child can interpret the meaning and recognize the significance of the information contained in a map, he must first be taught how to read the map. As Kohn puts it, "children need to learn how to read maps before they read maps to learn."[3]

Since maps play such an important role in today's social studies programs, map reading and map interpretation could be considered to be two of the fundamental skills to be developed in these programs. This view is quite in accordance with the opinions expressed by several of the leading writers in the social studies and geography fields. Bathurst,[4] Trail,[5] and others have repeatedly stressed the need for developing map readiness programs in order that children may have first-hand

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[3]Clyde Kohn, "Interpreting Maps and Globes," Skills in Social Studies, 24th Yearbook, National Council for the Social Studies, 1953 (Washington: NCSS), p. 146.

[4]Leonard H. Bathurst, "Developing Map Reading Skills," Journal of Geography, LX (January, 1961), pp. 26-32.

[5]Robert W. Trail, "Maps in the Primary Grades," Journal of Geography, LI (September, 1952), pp. 238-244.

experiences with maps as soon as possible. However, while most authorities agree that map programs should be begun in the elementary school, there is considerable disagreement as to what skills should be introduced and when the best time for their introduction might be.

A growing number of experts agree with the view expressed by Mitchell who states that "the ability to use maps ... must be taught in a carefully planned sequence beginning in the primary grades."[6] To some extent this advice has been followed and there are now a great many map programs being used in the primary grades. Few, however, take cognizance of the child's level of development of those concepts basic to an understanding of the skills the programs seek to foster.

If this situation is to be rectified, we should heed the advice offered by Kohn when he remarked that "special efforts must be made to develop particular skills at a time when the student is mentally capable of understanding a certain concept."[7] If this were done and the sequential development of certain concepts could be established, then map study programs could be designed which would introduce skills and understandings at a time when the child could readily understand and utilize them.

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[6]Edna S. Mitchell, "Introducing Maps - A Skill," Childhood Education, XXXVII (February, 1961), p. 279.

[7]Kohn, op. cit., p. 146.

The development of such programs at this time is not possible due to the lack of research regarding children's conceptual development in those areas pertaining to map work. As Barton points out,

> It is impossible to design (such) a precise numbered sequence for developing geography skills because as yet insufficient evidence has been collected by research in the behavioural sciences, experimental teaching, diagnostic testing and other kinds of research.
>
> All that is available today are some suppositions as to what is or what is not too difficult for various groupings, and some suggestions concerning a sequence of techniques based on limited observation, logic and judgment.[8]

Since a fuller understanding of the growth and development of children's concepts is greatly needed and since concepts related to the child's conception of space affect so many of his school subjects, it is hoped that the results of this study will make a significant contribution to our knowledge of the development of certain spatial concepts in children. If this intention is realized, this study should have important implications in those areas concerned with children's spatial orientation or perception of space. More specifically, it is hoped that the findings of this investigation will serve in some measure to alleviate the present deficiency of information concerning the growth and development of children's concepts which

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[8]Thomas Frank Barton, "Geography Skills and Techniques," Curriculum Guide for Geographic Education, Wilhelmina Hill, (ed.) (Oklahoma City: Harlow Co., 1964), p. 69.

pertain to map reading and interpretation. Furthermore it is the hope of the investigator that this study will prove valuable in providing educators with data which will aid the latter to design courses and materials which will more adequately meet the needs of children at various ages and levels of ability.

V. DEFINITIONS OF TERMS

Reference System and System of References - A complex network consisting of relations of order applied simultaneously to three dimensions. Objects within such a network are interrelated in terms of their locations relative to these three dimensions.

Coordinate Axes - This term shall be used to mean a network of relations of order applied simultaneously in two directions.

Scale - The proportion that a replica bears to the thing it represents.

Direction - The orientation of the line leading from a given place or object to another place or object.

Distance - The space between two objects.

Artificial Coordinate Axes System - An axes system consisting of two straight lines intersecting at right angles to each other and being parallel to the sides of the ground on which they are placed.

Natural Coordinate Axes System - An axes system consisting of any two lines intersecting in a manner which might occur in nature.

High Socio-economic Status - This term refers to a subject whose father's occupation (or mother's in the event that the mother supports the family) ranks above the median of class four of the Blishen Occupational Class Scale.[9]

Low Socio-economic Status - This term refers to a subject whose father's occupation (or mother's in the event that the mother supports the family) ranks below the median of class four of the Blishen Occupational Class Scale.

Grade Level - This term shall be used to mean the elementary school grade in which the subject was enrolled at the time of the investigation. Since repeaters were excluded from the sample, this term may also be considered synonymous with "number of years of schooling."

Concept - A concept may be defined as the resultant of a generalizing mental operation in which a generic mental image is abstracted from percepts.

Concept of Space - Spatial concepts are generalizations about the relationships that exist between certain kinds of data pertaining to one's perception and representation of space. These relationships are the fundamental abstractions which comprise the basic ideas about space. They are not tied to concrete objects or specific examples of actions or symbols, but are internalized generalizations and as such exist only in the mind.

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[9] B. R. Blishen, The Construction and Use of an Occupational Class Scale," Canadian Society, B. R. Blishen, (ed.), New York: McMillan (The Free Press of Glencoe, Inc.), 1961, pp. 477-485.

VI. THE EXPERIMENTAL SETTING

The experimental design and the statistical procedures used in analyzing the results of the study will be described in detail in Chapter III. The following outline of the experimental setting is included here in order to give the reader an overall view of the study.

A sample of one hundred and thirty-two children was selected at random from three schools in the Edmonton Public School System. A total of twelve subjects, one male and one female from each grade, one through six, was used for a pilot study. The remaining one hundred and twenty subjects comprised the sample for the main experiment. A test made up of a battery of five subtests each of which contained several items was designed by the author and administered to each subject. Some of these test items were patterned after those used by Piaget in his investigation of spatial concepts, however, since the majority of the items were devised for the express purpose of this investigation and had not been used previously, all the items will be statistically analyzed in an attempt to establish their appropriateness.

In almost every case the item required a response from the subject in which he performed some manipulative action with real three-dimensional objects. Subtest V is the only exception. Here the child manipulated some three-dimensional objects and then selected one of a group of two-dimensional objects. Subtest I

consisted of eight items and was designed to test the subject's ability to use an artificial axes system in locating objects. Subtest II had five items and examined the subject's concept of distance. Subtest III contained nine items and involved the subject in using a natural axes system to locate reference objects. Subtest IV, and its three items was designed to investigate the subject's use of reference points in locating a certain direction. Subtest V consisted of five items and was devised to study the subject's concept of scale.

The test was administered to the subjects in an individual testing session. The test program was carried out during the last two weeks of May and the first two weeks of June 1965.

VII. OUTLINE OF THE REPORT

The present chapter states the problem and is an introduction to and a preview of the study. Chapter II will present a review of the literature related to the problem and the study itself. Chapter III will describe the experimental design in detail and will discuss the statistical procedures used in analyzing the data. Chapter IV will consist of the results of the analysis of the data and will describe the observations noted during the testing program. Chapter V will summarize the study and will include the conclusions, implications and suggestions for further research.

CHAPTER II

A REVIEW OF THE RELATED LITERATURE

This chapter contains a review of both the literature related to children's concept formation in general and those studies which are specifically related to the development of children's concepts of space. A discussion and summary of this literature is provided at the end of the chapter.

Educators have long recognized the fact that children's spatial concepts play an important role in their perception and representation of the world about them. Accordingly, several tests have been devised which contain sections designed to measure certain of children's spatial abilities. However, the increasing interest which is being shown in the manner in which spatial concepts develop is a relatively recent occurrance and as a result there is a paucity of research which attempts to trace conceptual development in this area. Nevertheless, it is this kind of research which promises to be most beneficial for those interested in educating children. If concepts develop in an orderly, sequential manner, and if a child's stage of conceptual development for a certain concept could be identified, then educators would know exactly where to begin in order to help the child develop that concept in its entirety.

I. LITERATURE RELATED TO CHILDRENS' CONCEPT FORMATION

The exact nature of concept formation in children has been the subject of a great deal of interest and research but as yet our knowledge of this aspect of learning is not complete. Hurlock (1956) suggests that the formation of concepts in children follows a pattern in which sensory exploration is followed by motor manipulation which in turn is followed by questions about things which arouse the child's curiosity. She also points out that many factors can influence concept formation and that there are indications that sense organ deficiency, intelligence, opportunity for learning, concrete and vicarious experiences and social class differences all have some effect on the acquisition of concepts.

Vinacke, (1951, 1952) who reviewed several studies of the child's formation of concepts, concludes that,

> Children's concepts change with increasing age, but more in the form of a gradual progression (toward greater accuracy or more informed understanding, perhaps), than of definite stages. The change does not occur at the same rate for all children. Indeed, some may never achieve the more advanced kinds of explanation at all, since even adults may display concepts similar to those of children. Further, no child at a particular age gives consistent responses of one type or another, but instead may give many different types of response, depending upon the situation.[10]

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[10]W. E. Vinacke, The Psychology of Thinking (New York: McGraw-Hill Book Co., Inc. 1952), p. 117.

In his discussion of the conditions related to concept formation in children, Vinacke claims that several factors affect this formation in varying degrees. These factors are: age, intelligence, training or experience, socio-economic status and vocabulary. He also points out that the precise relationship between these factors and concept formation has not yet been worked out but that it appears that intelligence may not be as important a factor as either chronological age or mental age. He further notes that socio-economic status has been reported to have very little relation to scores on tests of conceptual development.

II. STUDIES RELATED TO THE DEVELOPMENT OF CHILDRENS' CONCEPTS OF SPACE

Researchers in this area have repeatedly tried to determine the exact nature of the development of these concepts and have attempted to discover whether they develop in a sequential pattern or not.

Probably the most extensive and intensive study of the child's conception of space was that undertaken by Jean Piaget in collaboration with Barbel Inhelder in Geneva, Switzerland (1963). While dealing briefly with the child's knowledge of space, the major emphasis of the study was on the development of the child's representations of space as opposed to his space perceptions. That

is, the research dealt with intellectual development, the development of intelligence as it operates on spatial relationships.

The major hypothesis was that in the child's ontogenetic development of spatial concepts, Euclidean and projective notions of space are preceeded by topological differentiations.[11] The investigators also attempted to show that actions rather than perceptions are the basic elements in such a developmental progression and that the final stage in this development is the result of a long and arduous period of construction.

Children's conceptions of the three classifications of space were examined by a series of unique experiments performed with an unspecified number of children ranging in age from approximately two to thirteen years. These experiments were usually a combination of manipulative type tasks, observation and interview. Piaget and Inhelder refer to this as their "clinical" method.

During the discussion of the child's transition from projective to Euclidian concepts of space, Piaget deals with the necessity of a system of references for the orientation of objects in space. According to his findings, the concepts of the straight line and of parallelism form the starting point for the coordination of directions in space and these are not completed until the level

[11] It should be noted that recent investigations by Fisher and Gracey (1963) have cast some doubt as to the validity of Piaget's "topological-primacy" hypothesis. These investigators suggest that the child's lack of verbal categories which can be applied to linear shapes may account for his apparent inability to distinguish linear from topological shapes.

of Euclidian concepts. It is not until the latter stage (age eleven or twelve) that the construction of true coordinate systems or frames of references occur. Piaget stresses the importance of this concept and states that "it is due to the spontaneous construction of such a network (reference system) that figures can be oriented and movements directed in space ..."[12]

In order to examine the development of this concept, Piaget first studied the emergence of the concept of vertical and horizontal axis. The underlying theory was that this concept was a prerequisite to the development of the concept of a coordinate axes system. The findings of this part of the study indicated that children became aware of horizontals and verticals as part of an overall system of coordinates at about the age of nine.

The next area to be investigated was whether a child could apply reference systems in attempting to reproduce particular arrangements of positions and distances. One of the methods used in the examination of this problem was as follows. A number of counters were arranged in an arbitrary fashion on top of a table and the child was asked to reproduce this figure using similar counters. After the subject's first attempt, he was given a number of rectangular strips of paper and asked if they might be used to assist him. In order to help the child, the examiner then showed him (on another figure) how to place the paper strips to

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[12]Jean Piaget and Barbel Inhelder, The Child's Conception of Space (London: Routledge and Kegan Paul, 1963), p. 376.

form a coordinate axes system so that the location of a counter might be viewed relative to one or more strips. The subject was then asked to try the original pattern once again. Additional patterns varying in complexity and number of counters were presented to the child in a similar manner.

On the basis of this experiment Piaget and Inhelder identified four stages in the development of general systems of reference. Unfortunately, the ages bordering these stages are not always specified and the investigators record only the following information.

The tests are ineffective at Stage I (no ages given). In Stage II, the subjects make no attempt to make use of reference systems and are incapable of understanding how to apply them even when shown. Only the figure itself is considered and any external reference system is ignored. Sample responses of three children are quoted for this stage, their ages being given as ranging from six years two months to seven years two months.

In Stage III, the subjects begin to use references separate from the parts of the figures, however, they cannot coordinate the relative distances and the true positions of the counters in an all-encompassing manner. The ages for this stage are given as ranging from approximately eight years three months, to nine years one month.

It is not until Stage IV that the subjects are capable of using conventional reference systems correctly. The authors stated this as follows:

> Only after the age of 11-12, during the stage of formal operations of thought, are true conventional reference systems developed, enabling positions and distances to be compared simultaneously.[13]

Another experiment which Piaget and Inhelder describe was performed in order to examine the child's development of the concept of a natural axes system. The latter was provided for the child in the form of a path and a stream on a three-dimensional model of a farm. The method required the child to replicate the exact placement of a doll on one model by placing a similar doll on another model (identical to the first one) which had been turned 180^{o}.

On the basis of their findings, Piaget and Inhelder claim that this concept develops in three successive stages. In Stage I (up to approximately three years six months to four years) the positions are located mainly through topological relationships of proximity and surrounding or enclosure. That is, the child places the doll in any field without concerning himself with left-right, before-behind relations, distances or the rotation of the model. During Stage II (four to seven years) the child locates the doll relative to his own position and disregards the rotation of the model, however, he does take account of a number of relationships and no longer relies simply on the proximity of surrounding objects. With the appearance of Stage III (between six and a half to seven years) the child can place the doll with complete accuracy for all

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[13] Ibid., p. 414.

positions due to the fact that all relationships are arrived at by logical multiplication.

In addition to these experiments, the authors also administered a test which required children to draw an object (a building, tree, etc.) from a certain point of view and on a reduced scale. Based on the findings of this experiment, the investigators claim that the ability to use scale appears in Stage IIIB (seven to ten years) and is perfected in Stage IV (eleven to thirteen years) or the stage of formal operations.

Piaget's work has created a great deal of interest and it has also given rise to considerable criticism. In general, there are three major aspects which are criticized most often: the methods employed in the experiments, the treatment of the data collected, and the reporting of the study as a whole.

The "clinical" method employed by Piaget is one in which no attempt is made to control variables or to take account of such factors as intelligence or sex. The findings appear to be based solely on a combination of interview and observation of groups of subjects the number and nature of which is seldom disclosed. The ages defining the stages of development which are identified through these procedures appear to be somewhat arbitrary and flexible since the responses of one subject are often given as examples of different stages in various concepts. In addition the report itself is written in highly technical language full of allusions to logic and theoretical models which the authors do not fully explain. Probably the most

serious criticisms arise from the fact that Piaget applies no statistical procedures to his results in an attempt to validate them.

Despite its drawbacks, this work on the child's conception of space has proved to be very valuable in adding to our knowledge of the psychological and logical processes involved in the acquisition of concepts. Leaving aside the question of the validity and reliability of the findings, it must be admitted that the authors have presented a most interesting rationale of the manner in which experiences, maturity and logical thought processes are combined in the sequential development of children's concepts of space.

At the present time there are no reported studies which have attempted to replicate Piaget and Inhelder's study in its entirety. There are, however, a few studies which have investigated selected aspects of their findings. Two such studies were conducted in Britain and have been reported by Peel and Lovell.

Peel (1959) has reported a study in which he attempted to replicate several aspects of Piaget's work concerning perception and thinking. In the area of spatial concepts, Peel investigated children's haptic perceptions and their knowledge of spatial relationships as revealed in drawings. For this part of his study at least, Peel concluded that his findings served to substantiate Piaget's general theory regarding the ages and stages in which children acquire these concepts.

A somewhat similar study was reported by Lovell (1959) who

investigated a number of Piaget's findings in the area of spatial concepts. Like Peel, Lovell conducted his study with British children and examined the growth of concepts of haptic perception and spatial relationships in drawings. In addition, Lovell replicated Piaget's experiments on linear and circular order, knots, and projective and straight lines. Lovell reported that his findings partially substantiated Piaget's, but that there was often a discrepancy between the ages Piaget lists for certain stages of development and the ages that Lovell found for similar stages.

A study which bears directly on the present investigation has been reported by Beard (1964). This study was conducted in Britain with the purpose of examining the conceptions of horizontal and vertical among primary school children. The procedure used was a direct replication of Piaget's experiments involving horizontals in jars of liquid, verticals as indicated by a plumb line and the drawing of houses and poles on a hill. Several college student investigators administered these tests to a total of 200 school children between the ages of six and eleven. Based on their findings, the investigators concluded that the acquisition of the concept of horizontal and vertical occurred later in this sample of English children than in Piaget's sample of Swiss children and that this concept appeared to develop separately and in specific situations for the former group. In general, it was found that age and intelligence were important factors in the development of this concept and that there were substantial

differences between sexes to the advantage of the boys.

One of the few Canadian studies in this area was conducted by Dodwell (1963) in which he attempted to assess the generality of the sorts of spatial concepts and their development as reported by Piaget. His sample consisted of 194 children ranging in age from five years one month to eleven years three months. The intelligence quotients of this sample ranged from eighty-three to one hundred and thirty-six. The experimental design of the study consisted of administering replications of those tests Piaget designed to assess understanding of horizontal and vertical coordinates. Dodwell observed all the stages and substages described by Piaget but found that there was a wide range of ages for each stage and that there was very little regularity in the developmental pattern. In general, it was concluded that an over-all ability to deal with spatial concepts increased with age.

Concepts of a horizontal and vertical are prerequisites to a reference system and there are a few studies which bear either directly or indirectly on the latter. One such study was conducted by Rivoire (1962) who undertook to determine if a definite series of ontogenetic developmental stages for the concept of space could be determined. One hundred and forty-four children were used in this study and were administered a form test devised by the author. This test consisted of items designed to enable Rivoire to examine concepts in each of the four types of space: topological, affine, projective, and Euclidian.

Rivoire found that topological notions of space developed later for her sample than they did for Piaget's while projective concepts emerged earlier. She also found that a concept of reference systems occurred later in her sample than in Piaget's and that many of her fourteen-year-old subjects had not developed Euclidian concepts while some children had fairly well established concepts as early as the age of four. Sex was not found to have any effect on the formations of these concepts.

A study which dealt with spatial concepts as related to maps was conducted by Satterly (1964) who attempted to identify common problems, skills and concepts upon which the drawing and reading of maps depends. In this study a number of tests were administered to sixty children between the ages of fourteen and fifteen and some of the results were compared with Piaget's findings. Satterly concluded that perceptual ability in general and the attainment of a concept of space were fundamental to a child's ability to read and understand a map. He also concluded that despite Piaget's claim that children can understand and utilize true reference systems at approximately the ages of eleven or twelve, this stage of conceptual development had not been reached by several of his subjects of fifteen years of age or more.

Another study which investigated children's abilities in mastering certain map skills is reported by Sorohan (1962). In this study eleven map skills were taught to a sample of 498 pupils in grades four, five, and six in Ohio. After the skills had been

taught, Sorohan evaluated the effect of these procedures at each grade level in an attempt to discover the most effective grade placement for each skill.

Two of his findings are of particular interest to this thesis. In terms of the child's understanding of the use of a grid system for location, Sorohan concluded that this understanding can be mastered only by pupils with a mental age above 161 months. This is in agreement with the findings reported by Piaget. However, one finding which did not concur with Piaget's concerned the child's ability to understand scale. While Sorohan investigated a slightly different aspect of this concept, namely the child's ability to understand a scale of miles rather than scale *per se*, he nevertheless found that no child in his total sample had a fully developed understanding of this concept.

Prior (1959) also conducted a study to discover the connection between mental age, and the ability to understand maps. It was conducted with 250 junior school children (ages nine to eleven) in Britain. Prior devised tests which required the subjects to draw maps of a model village, to reconstruct the model from their maps and to locate neighbouring cities on a map of England.

Based on the results of her study, Prior concluded that children cannot understand or interpret maps until they have reached a mental age of at least ten years, seven months. In addition she claims to have substantiated Piaget's findings with regard to scale, that is, that the child first becomes aware of scale somewhere between the ages of nine and ten.

Prior's study, while contributing to our knowledge in this area, is reported in a singular fashion in which very brief and incomplete descriptions are given of the sample, the tests and testing situation. The lack of clarity regarding the measures used to arrive at some of her conclusions could be considered to render the latter open to question.

III. DISCUSSION AND SUMMARY

A review of the research indicates that there are relatively few studies which have investigated the development of children's spatial concepts and that the study conducted by Piaget and Inhelder appears to be the most comprehensive investigation to date. This latter study, while subject to much criticism regarding certain of its aspects, has given rise to an increasing number of separate experiments and replications of parts of the original work in an attempt to examine conceptual development more fully. However, as yet, our knowledge of the precise manner in which these concepts develop is far from complete. The extent of our present knowledge in this area may be summarized by the following generalizations.

1. Concepts are the results of complex mental processes in which percepts, sensory-motor impressions and past experiences are linked together in selective systems.

2. The development of concepts is a gradual and prolonged process which begins in very early childhood and may extend into

adulthood.

3. It appears that a number of factors affect concept formation in some way, however, our knowledge of the degree to which these factors affect concepts and the precise manner of their influence is not fully understood.

4. Some of the factors which have been shown to be influential in concpet formation are: chronological age, intelligence, mental age, socio-economic status, training or experience and vocabulary.

5. On the basis of the studies conducted to date, it would appear that children's conceptions of space develop in a sequential pattern or in a series of stages. However, while every child must pass through all the stages to acquire a given concept in its entirety, there is no assurance that every child will do this, nor is there any guarantee that every child will progress at the same rate of development.

6. While the ages and stages of conceptual development have been defined by some investigators, there are definite indications that these ages and stages may vary greatly for different groups of individuals.

7. Concept formation appears to proceed in a definite order but there is reason to believe that the concepts of any one child may be in several different stages of development simultaneously.

CHAPTER III

THE EXPERIMENTAL DESIGN AND STATISTICAL PROCEDURES

This chapter contains an explanation of the selection of the sample, a detailed description of the test battery and its administration, and a discussion of the statistical procedures used to analyze the results of the study

I. THE SAMPLE

The sample was selected from three elementary schools of the Edmonton Public School System. One school was used solely for the purpose of conducting the pilot study. The sample of subjects for the main investigation consisted of 120 pupils drawn from the two other schools.

The reason for the selection of two schools was twofold. First, since the effect of socio-economic status was to be studied, it was advantageous to draw one half of the sample from a school located in one socio-economic area and the other half from a school in a different socio-economic area. Several school areas were visited and the principals of these schools were interviewed by the investigator. On the basis of this procedure one school

was selected from an area which the investigator considered to be high in socio-economic status and a second school was selected from an area which was considered to be lower in socio-economic status. This method ensured that there would be some degree of divergence in the social class membership of the members of the sample. Secondly, for purely practical reasons it was more feasible to use two schools for the testing program. In this way the disruption of pupil's and teacher's schedules was kept to a minimum.

The procedures used in the selection of the sample were as follows. In each school a number was assigned to each child in every grade one through six inclusive. Next, for each sex, a table of random numbers was consulted and five numbers were chosen representing five subjects.[14] This was repeated in each grade. The resultant sample consisted of ten males and ten females from each grade making a total of 120 subjects. Pupils who had repeated a grade were excluded from the sample as were recent immigrants who might have experienced language difficulties in understanding the test instructions.

The sample for the pilot study was selected in the same manner with the exception that only one male and one female was chosen from each grade making a total of twelve subjects. An explanatory letter (see Appendix A) briefly describing the purpose of this study was sent to the parents of every child in the sample.

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[14] Herbert Arkin and Raymong Colton, Tables for Statisticians (New York: Barnes and Noble Inc., 1950), pp. 142-145.

II. THE INSTRUMENT

Each subject was involved in two separate testing situations. In the first session an intelligence test was administered. The test used was the non-verbal, Lorge-Thorndike Intelligence Test, form B.[15] The second session was an individual testing situation in which a test containing a battery of five subtests was administered. This battery of subtests was designed by the investigator and had never been administered before. It should be noted, however, that some of the items were patterned after tests used by Piaget in his investigations. In addition to these, original items were devised for inclusion in the test battery.

In order to refine the test and to ensure that the instructions to be used in administering it would be comprehensible to the subjects to be used in the investigation, the test was administered to a pilot group of twelve pupils who did not form part of the sample. On the basis of this pilot study, revisions were made and the difficulties which arose in the course of this preliminary investigation were minimized.

The revised form of the test (see Appendix B) consisted of five subtests each of which was designed to examine the degree to which a subject had acquired a certain concept. Each subtest contained from three to nine items. A description of the test, its subtests and the names of the concepts they were designed to measure follows.

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[15] Irving Lorge and Robert L. Thorndike, Boston: Houghton Mifflin Co., 1957.

I. Artificial Axes.

This subtest was designed to measure the subject's development of the concept of a reference system utilizing artificial axes. Through the use of this subtest an attempt was made to discover whether this concept could be utilized in the replication of a spatial configuration.

The necessary apparatus consisted of eight, eleven by sixteen inch sheets of cardboard and forty-five plain, white, one and one half inch poker chips which were used as markers. Four of the cards had markers fastened on them in patterns and four had no markers. The configurations of the four patterns were determined by ruling each card into seventy-seven equal squares, numbering each square and then selecting eight numbers from a table of random numbers to represent the squares where markers were to be fastened. Patterns in which three or more markers were contiguous were discarded as it was felt that configurations of this type might prove to be easier than others for the child to copy

It was theorized that if the child had developed the concept of a reference system involving artificial coordinate axes, he would be able to utilize these axes in making an accurate replication of a pattern of markers. In order to examine this theory in detail, the four cards were provided with varying degrees of cues to artificial coordinate axes systems. Card 1 had no markings of any kind whatsoever on it, on card 2 one marker (selected at random) had small axes marked on it, card 3 had large axes bisecting

it horizontally and vertically and extending to the edges of the card, and card 4 was marked with double axes making a nine sectioned grid system. Each of these four cards was paired with a card which was similarly marked but without the markers. In each pair, the first card contained the pattern the child was required to copy and the second card was the ground on which the pattern was to be replicated. Figures 1, 2, 3, and 4 illustrate the patterns used on the four cards.

In the administration of these items the subject was seated at a table facing the investigator and the sets of cards were presented in the following manner. Both cards were placed on the table in front of the subject, the card containing the pattern furthest away from him. In addition, he was given thirteen markers one of which had small coordinate axes on it. This marker was to be used for the second pair of cards.

In every case the sets of cards were presented to the subject in two different orientations. First, the cards were placed so that the card with the pattern was turned through an angle of 90° relative to the blank card immediately in front of the child. (see Figure 5)

After the subject had attempted all four items in this manner, the rotated card was placed parallel to the blank card (see Figure 6) and the child went through the sequence again. The cards were rotated in an attempt to discover (1) whether the subject would take account of this discrepancy in orientation,

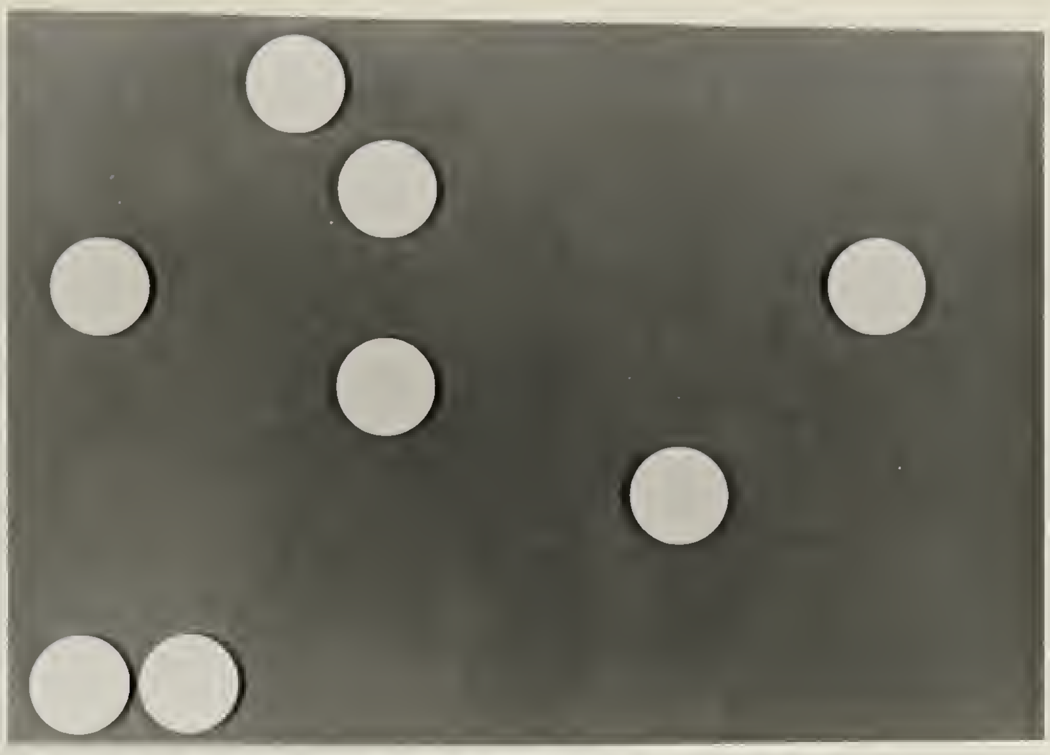

Figure 1. The Card Used in Item One.

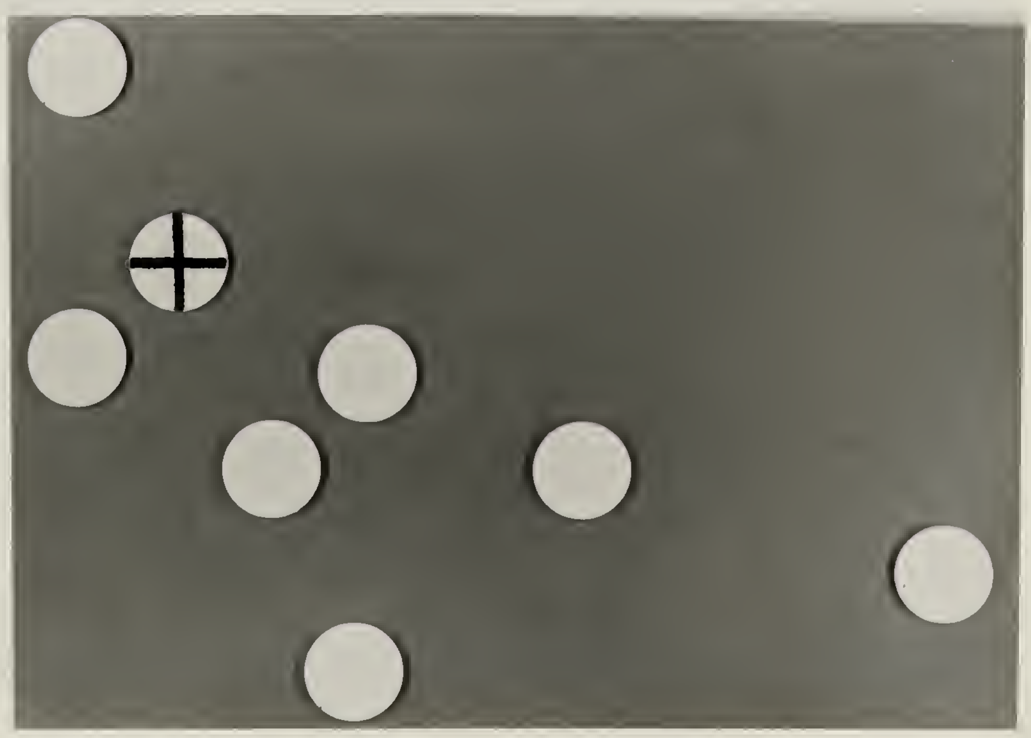

Figure 2. The Card Used in Item Two.

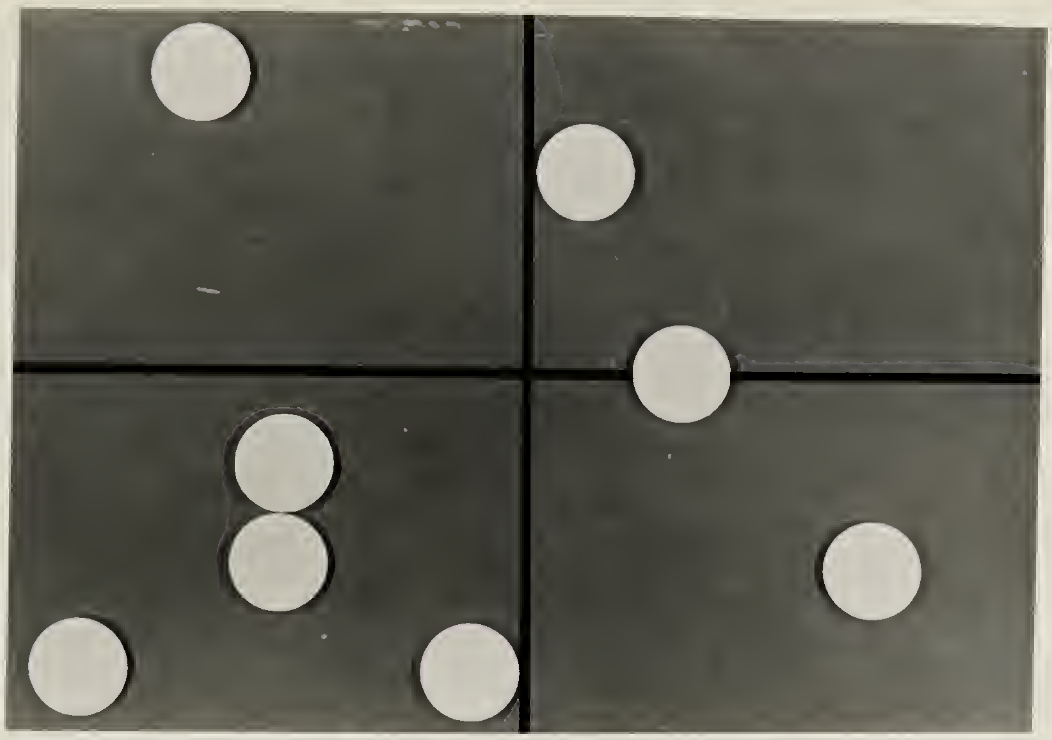

Figure 3. The Card Used in Item Three.

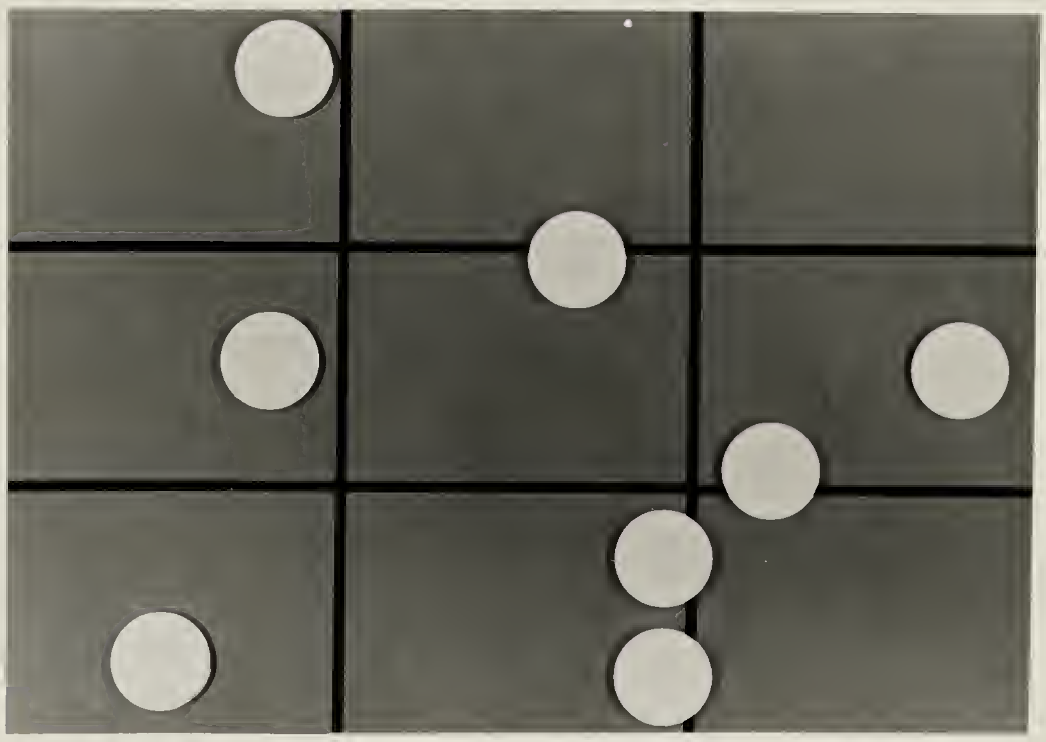

Figure 4. The Card Used in Item Four.

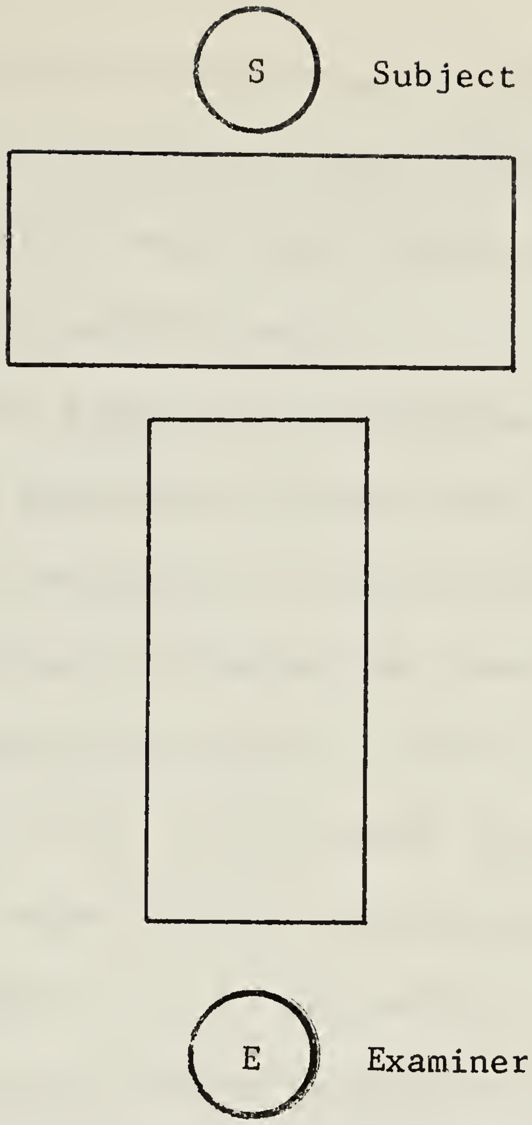

Figure 5. Position of Cards for Subtest I in a Rotated Orientation.

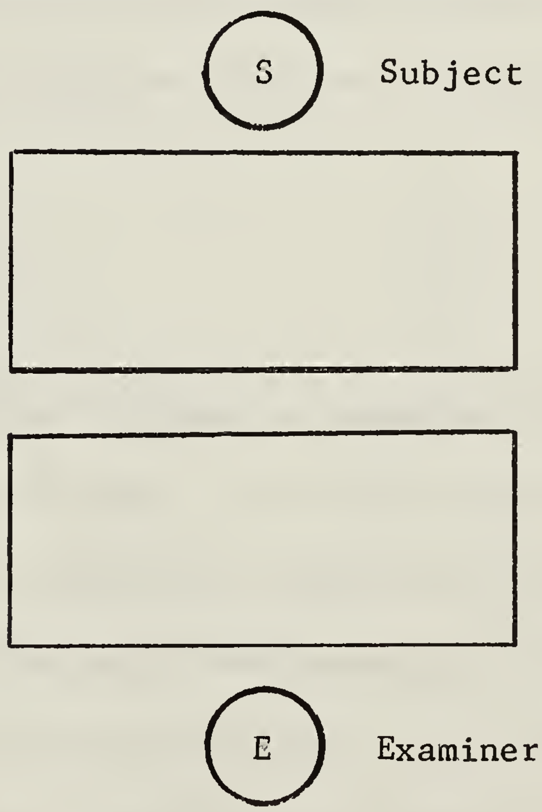

Figure 6. Position of Cards for Subtest I in a Parallel Orientation.

(2) if he could mentally turn the rotated card to align it with the blank card, and (3) which orientation would present the most difficulty to the child. Every child worked through four rotated cards followed by four parallel cards.

Since there was a possibility that some learning might occur during the subject's progression through these items in the order outlined above, the contingency of such an effect was controlled for the entire sample by alternating the order in which the items were presented to successive subjects. That is, subject one worked as follows: items 1, 2, 3, 4 all rotated, then 5, 6, 7, 8 all parallel. The next subject worked through them in the order 4, 3, 2, 1 all rotated, then 8, 7, 6, 5 all parallel. A comparison of the scores of subjects who worked through the items in one order with the scores of subjects who worked through the items in the opposite order should indicate whether a learning effect did occur or not.

II. Distance.

This subtest was designed to examine the subject's development of a concept of distance. All five items which comprised the subtest were of the same general design and were always presented in the same order. The child was seated at a table upon which the examiner placed two three-dimensional objects with a specified distance between them. The child was asked to look carefully at this interval and was told that he would be given the objects to

replace on the table with exactly the same distance or space between them. Care was taken to make sure that the table top was completely blank and devoid of any marks which the subject might use as reference points in relocating the objects.

The variations in the five items took the form of different objects and different specified distances. The latter were arbitrarily set at eleven and one half, sixteen and one half, thirty and one half, seven and one half, and twelve and one half inches. The objects and their orientation as viewed by the child are illustrated in Figures 7 to 11 inclusive.

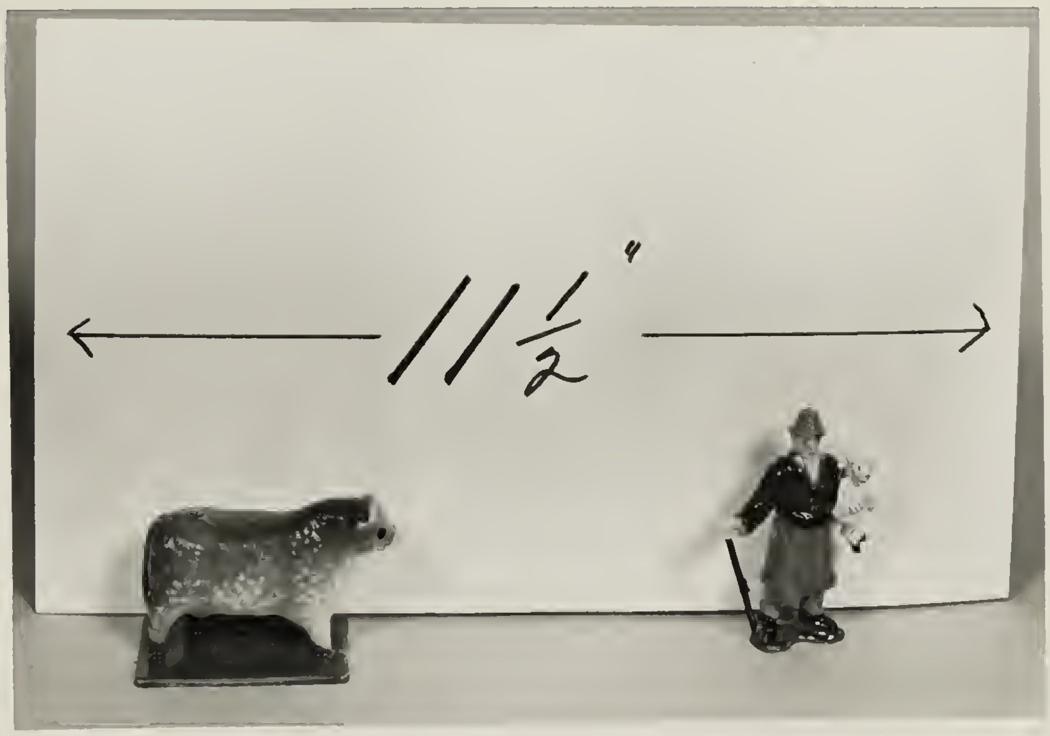

Figure 7. Objects Used in Item 1, Subtest II.

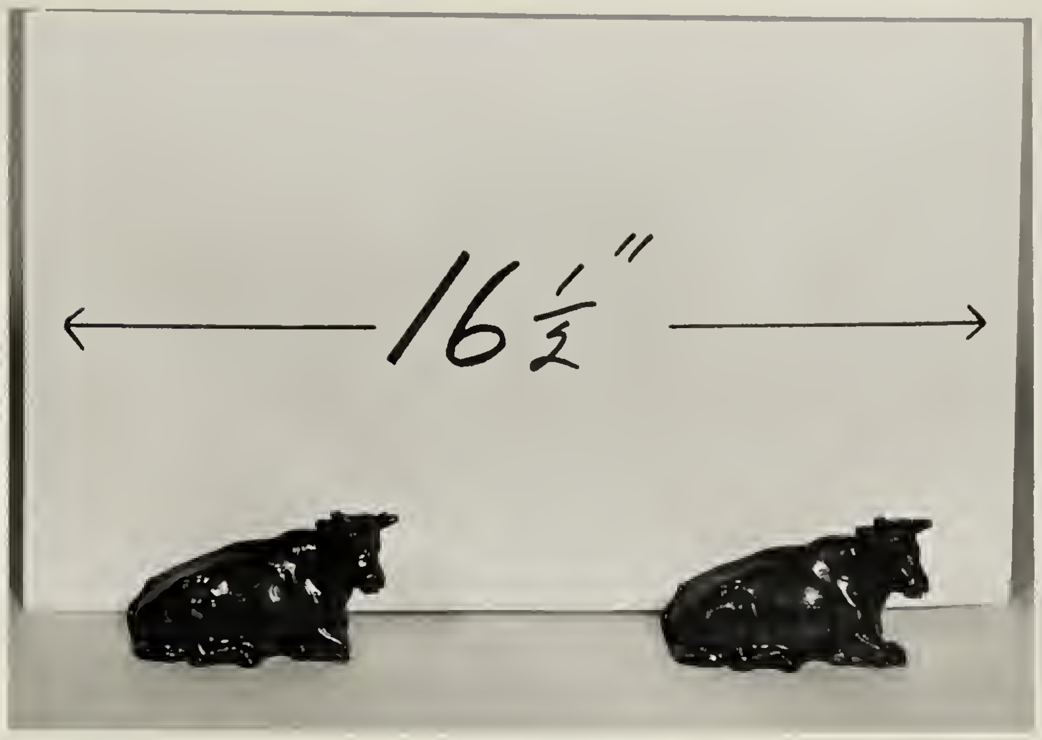

Figure 8. Objects Used in Item 2, Subtest II.

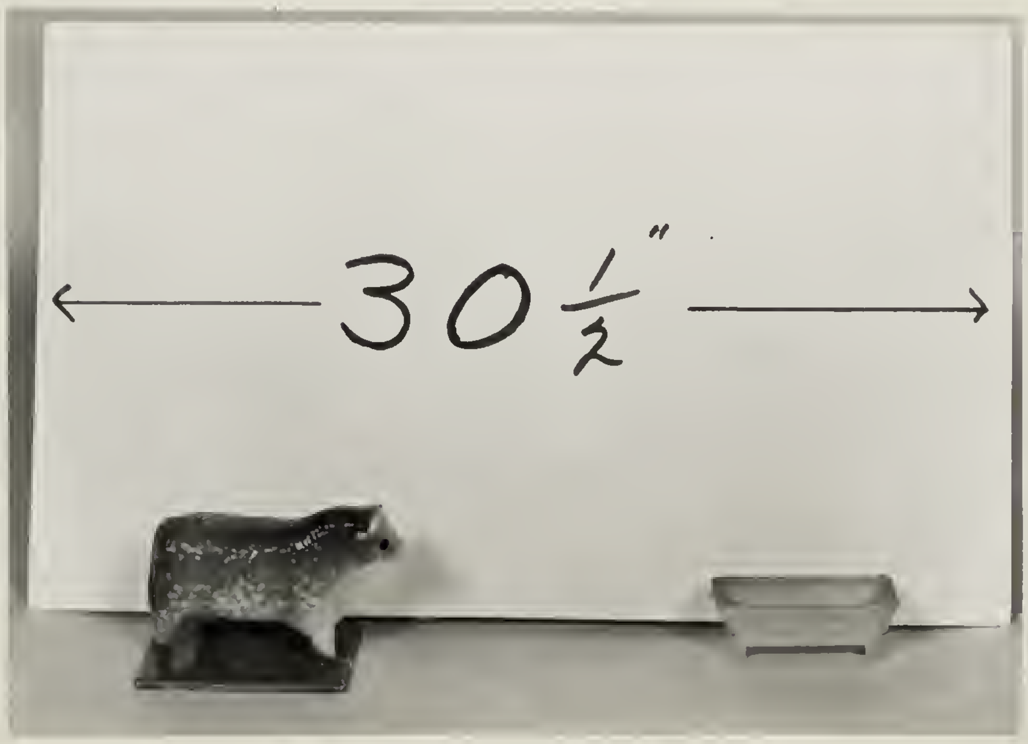

Figure 9. Objects Used in Item 3, Subtest II.

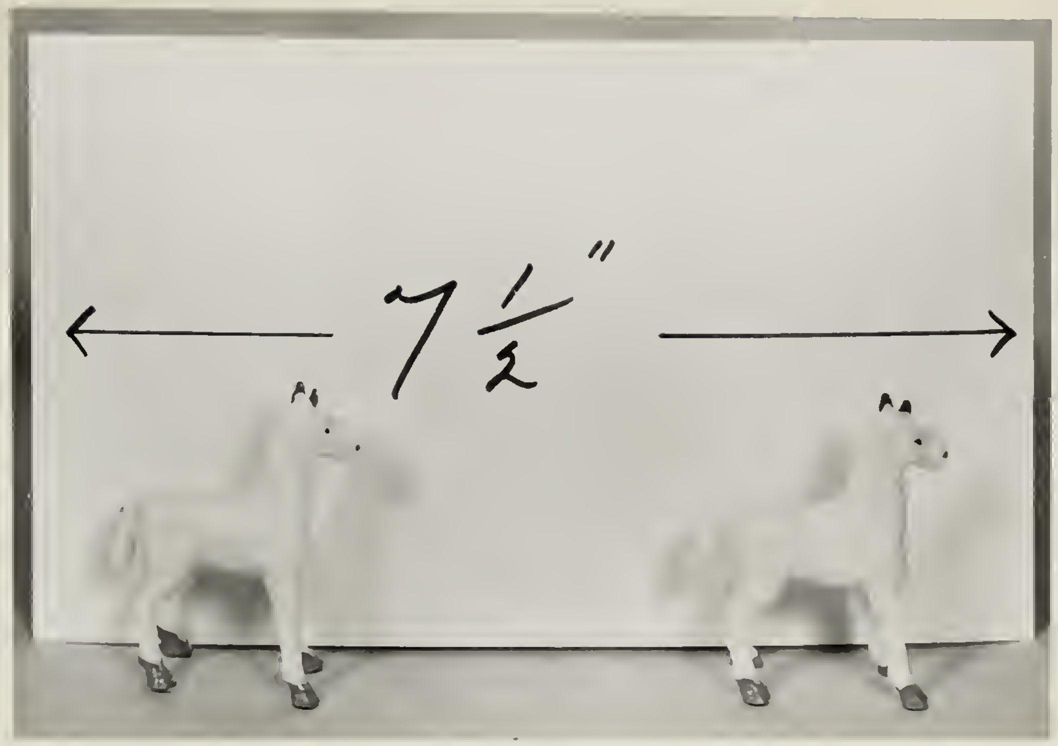

Figure 10. Objects Used in Item 4, Subtest II.

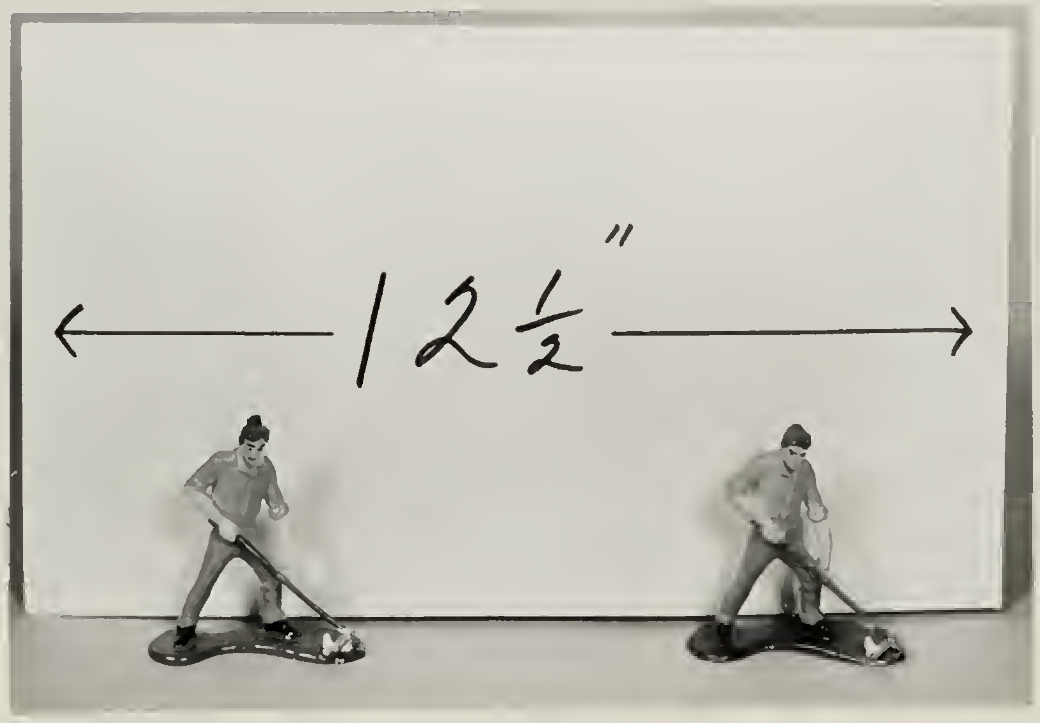

Figure 11. Objects Used In Item 5, Subtest II.

III. Natural Axes.

Patterned after a test used by Piaget, this subtest was designed to determine the degree to which the subject had developed the concept of a reference system involving a natural axes system. The apparatus for this part of the investigation consisted of two identical three-dimensional models of a farm, each of which was interesected by a road and a stream thus creating an artificial coordinate axes system. (see Figure 12)

Figure 12. One of the Models Used in Subtest III.

The models were placed beside each other on a long table and each subject was invited to satisfy himself as to their similarity. When this had been accomplished, a screen was placed between the models so that the subject could view only one at a time.

Each of the nine items which comprised the subtest required the child to watch while the investigator placed an object on the first model. An identical object was then given to the subject and he was instructed to place it on the second model in exactly the same location. In every case the objects were removed from both models as soon as the examiner or child had placed them. This was done to ensure that no object used for one of the items, might be used as a reference object for the location of the next object. In this way the child was forced to rely on the natural axes and the stationary objects for reference.

The screen served a double purpose. It prevented the subject from watching while the second model was rotated 90^{o}, 180^{o} and 270^{o} and it also prevented the subject from looking back at the first model in order to correct his placement of an object. The rotation of the second model prevented the child from using his position relative to the model as a basis for selecting the proper location for each object. This too forced him to rely on a combination of the natural axes and the farm buildings as reference objects in finding the correct location. Three objects were placed on the models for each rotation constituting a total of nine different test items.

IV. Direction.

This subtest contained three items and was designed to test for the existence and state of development of the child's concept of direction. The apparatus consisted of a pair of identical three-dimensional models of two roads intersecting at right angles. Objects which could be used for reference points were located in three of the four fields created by the intersection of the roads (see Figure 13). In addition, a toy truck was used in this part of the investigation.

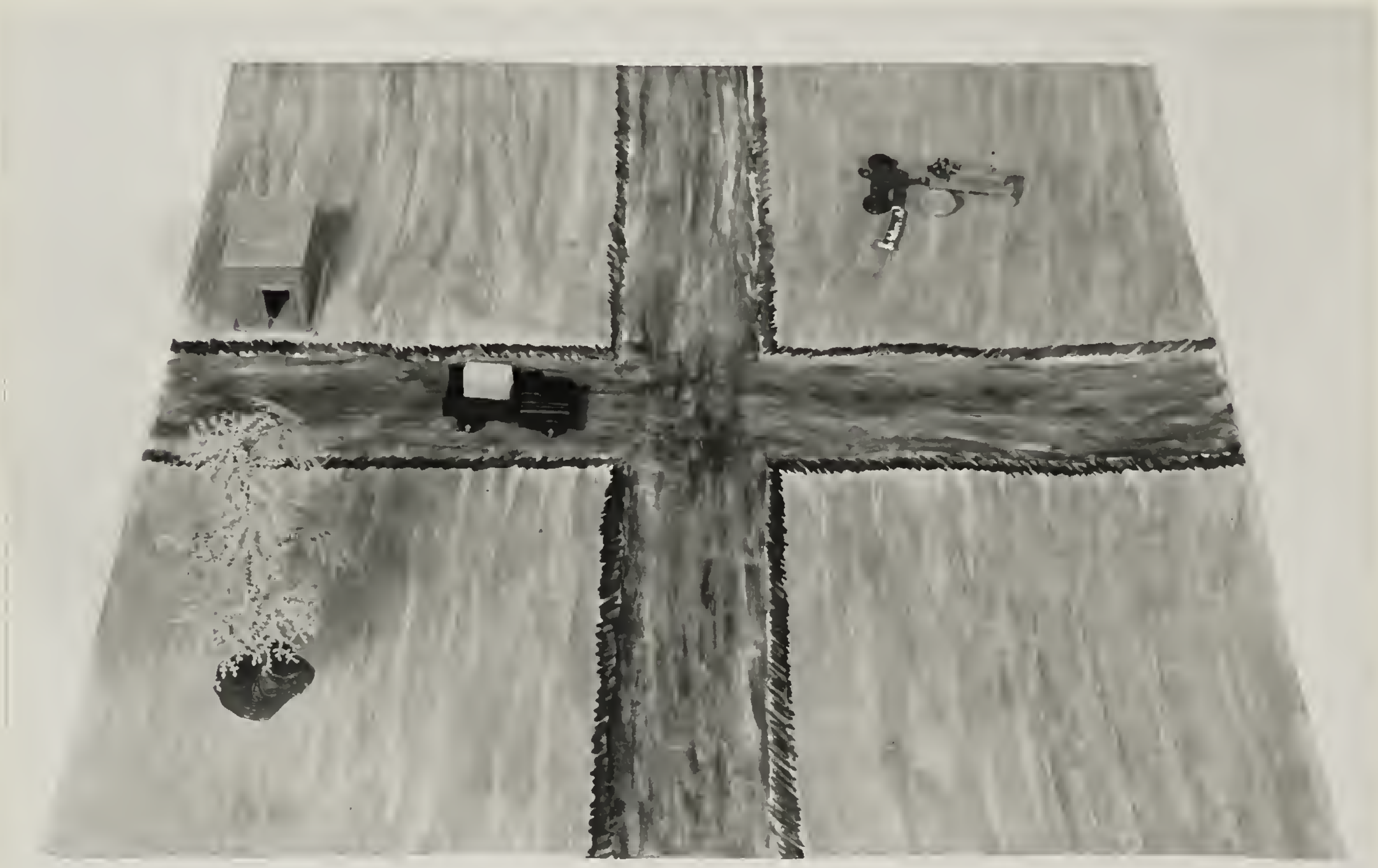

Figure 13. One of the Models Used in Subtest IV.

As in subtest III, the models were placed side by side on a long table and the child was invited to satisfy himeself as to their similarity, then a screen was placed between them. With the child standing before the first model and unable to see the second, the examiner told the subject a story about a farmer who had to take a bale of hay out of the shed (on the model) and drive to town. The hay was placed in the truck and the child was cautioned to take careful note of the direction the farmer must drive to reach the town since the subject would have to drive to town on the second model. The truck was then "driven" along the road and made to turn to the right at the crossroads. Next, the truck was handed to the child who then stepped around the screen to the second model and attempted to drive the truck in the correct direction. In the meantime, this model had surreptitiously been rotated through 180^{o}. The three items involved in this subtest were performed on the model when it has been turned 180^{o}, 90^{o} and 270^{o} in that order. In each case the child did not witness the rotation of the model and was asked to explain the reason for his decision regarding the direction to be taken.

V. Scale.

This subtest was designed to examine the state of development of the child's concept of scale. It contained five items. The apparatus used in this subtest is illustrated in Figure 14 and consisted of a large model of a farm, a piece of cardboard

one-quarter the size of the model and five cards upon which were fastened five cardboard shapes of various sizes. The model had three-dimensional buildings on it while the small piece of cardboard was completely blank. Since the child was required to work with two-dimensional representations of the three-dimensional buildings, the real objects were removed from the model and replaced with pieces of coloured cardboard the same size as the base of the objects they represented. This was done while the child looked on and he was then questioned to ensure his comprehension of the transition.

The instructions were again incorporated into a story and the child was told that the large diagrammatic layout was a map of a farmer's farm, but that the farmer wished to make another map of the farm on the other (smaller) piece of cardboard. The necessity of using the correct size of building for the smaller map was discussed, then the child was shown a card on which five sizes of one of the buildings were fastened and was asked to select the one which would be the correct size for the small "map".

The five items in the subtest required the child to choose the correct symbol for:

1. a rectangular barn,
2. a circular granary or silo
3. a rectangular shed,
4. an oval pond, and
5. a rectangular chicken coop.

In each case the two-dimensional representation was cut from cardboard the same colour as the real object and the placement of the sumbols on the card of five symbols was determined by random ordering each set separately.

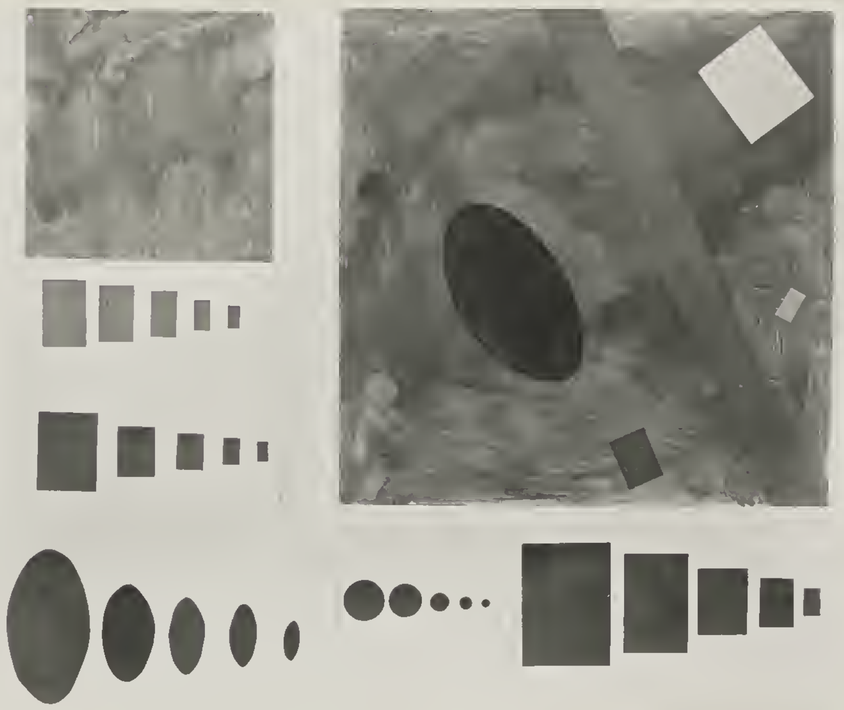

Figure 14. Apparatus Used in Subtest V.

III. THE TESTING PROGRAM AND METHOD OF SCORING

I. The Program.

The testing program was administered to the sample of 120 subjects during a four week period from the middle of May to the middle of June 1965. With the exception of the intelligence tests, which were administered to groups of pupils, all other tests were given in individual testing situations in a room apart from

the regular classrooms. Measures were taken to prevent any interruption of the testing session and only the investigator and one subject were present during any test.

The tests and apparatus for each item were arranged prior to the arrival of each subject in four testing stations around the room. Subtests I and II were conducted at the first station; all subsequent tests were located at separate stations.

Immediately prior to administering the intelligence tests and while the pupils were collected together in groups, the investigator talked to the subjects and gave a brief description of the testing situation in which they would be participating. This served to introduce the investigator to the children before the individual testing situation and enabled the former to answer questions and put the subjects at their ease. When each child entered the testing room for the battery of five subtests, acquaintance was renewed and the child was encouraged to examine the models before the test began. As a result of this procedure, all of the subjects cooperated fully during the testing and evidenced great interest in the tests. The period of time required for each session varied from twenty minutes to forty-five minutes. In all cases the subject's interest was maintained for the entire test period.

II. The Scoring.

The method used to score each subject's performance on the subtests was as follows:

Subtest I

Scoring for each of the items of this subtest was achieved by means of a set of four transparent plastic overlays. These sheets were the same size as the cards upon which the markers were placed and each one had eight rings one inch in diameter marked upon it. These rings corresponded to the location of the markers on the cards. The overlay was placed over the card upon which the subject had placed his markers and a score of one was assigned for each marker which intersected the ring on the overlay. If the marker did not intersect the ring, a mark of zero was given for the item. If the child used more markers than there were on the card to be copied (8), the number of extra markers was deducted from the total score for that item. The use of a transparent overlay permitted the scoring of items in which the subject had made a mirror image or a reflected copy of the pattern. In cases such as this the item was scored in the usual manner and a note was made of the transformation of the pattern.

Subtest II

When the objects were placed before the child, the distance between them was regulated by setting each object beside a strip of cardboard on which the length for that item has been marked. This strip was then removed from the table and hidden from view. After the child had replaced the objects, the cardboard strip was placed beside them and the similarity of the distance between the objects and the specified distance was checked. A small margin for error was allowed (two inches in each case) and a score of one or

zero was assigned depending upon whether or not the new distance fell within this margin or not.

Subtest III

In subtest III, performance on each item required the child to place an object in a certain location in a certain field. Since this called for both the location of the field and of a point within it, scores were assigned for both aspects of the item. That is, a score of one or zero was given depending upon whether or not the subject chose the correct field and a score following the same principle was given for the location of the object within the correct field. The accuracy of the latter was checked by means of a transparent overlay which incorporated a certain margin of error within it.

Subtest IV

In this subtest a mark of one or zero was assigned for each item depending upon whether the subject indicated the correct direction or not.

Subtest V

For each item in this subtest a score of one or zero was given depending upon whether the subject selected the symbol of the correct scale or not.

A copy of the score sheet which was used in the experiment is to be found in Appendix C. The information pertaining to chronological age and parental occupation was obtained from the child's cumulative record folder in the school.

Since each subtest was designed to examine the development of a specific concept, there was no reason to sum the scores of the five subtests. However, the total possible scores for subtests one to five were 64, 5, 18, 3 and 5, respectively.

IV. THE STATISTICAL PROCEDURES

Since all five subtests were designed by the investigator, it was decided that they ought to be subjected to some form of statistical analysis to determine the relationship between them and the degree to which they might be redundant. Consequently, the intercorrelations of all the items will be found. Due to the fact that some items were scored on a continuum while others were dichotomous in nature, two types of correlations will be employed. Pearson product-moment correlation coefficients will be found for all the items in subtests I and III and tetrachoric correlation coefficients will be calculated for the items in subtests II, IV and V. These intercorrelations between items should serve to indicate the degree to which each item under consideration is related to the others. If the items within each subtest were measuring the same thing, then it would be expected that there would be a high, positive correlation between them.

In order to assess the relationship between the subjects' scores on the subtests and the variables of sex, socio-economic status, chronological age, intelligence and grade level,

intercorrelations between the scores and these variables will be found. Biserial correlation coefficients will be calculated for the relationships between the variables of sex and socio-economic status and the test scores. Pearson product-moment correlation coefficients will be found for all other relationships. In addition, a two-way analysis of covariance will be used to determine the relationship between the scores of males and females on each subtest with intelligence held constant.

CHAPTER IV

THE RESULTS OF THE INVESTIGATION

This chapter will deal with a summary of the results for the total sample, the observations which arose from the testing situation and the analyses which were carried out.

I. SUMMARY OF THE RESULTS FOR THE TOTAL SAMPLE

The Sample

The sample used in this study consisted of 120 elementary school children from the public school system of Edmonton, Alberta, Canada. This sample was composed of ten males and ten females from each grade, one through six inclusive, making a total of twenty subjects from each grade. The age range of the sample was from six years seven months to twelve years seven months while the intelligence range as measured by the Lorge-Thorndike Intelligence test, non-verbal battery, form B, was from seventy-seven to one hundred forty-three. The composition of this group in terms of socio-economic status as measured by the Blishen Occupational Class Scale was forty-three high socio-economic status and seventy-seven low socio-economic status. The mean chronological age, and intelligence for the sample as a whole and for each

grade level of subjects are shown in table I.

The Test

A copy of the test used in this investigation is to be found in Appendix B. It contains five subtests each of which was designed to measure a specific concept.

Results of Subtest I - Artificial Axes

This subtest was designed to measure the subject's development of the concept of a reference system utilizing artificial axes. It consisted of 4 items which contained varying degrees of cues to an artificial coordinate axes system. These items were arranged in an order in which it was hypothesized that each succeeding item would be less difficult than the preceding one. Thus, if the hypothesis was correct, the subject would make an increasingly higher score if he progressed through the items in a 1, 2, 3, 4 order. The results of this subtest are presented in table II in which the mean score for each item, when it was presented in a rotated orientation is listed by grade level.

This table indicates that the items were not arranged in a progressively easier manner, but that on the average, each grade level of children found item 2 to be more difficult than item 1. An explanation of this finding might be that the pattern of item 2 was more difficult to replicate than the pattern of item 1 despite the fact that a cue to a reference system was provided by one marker which had an axes system on it. The results of this

TABLE I

MEAN CHRONOLOGICAL AGE, AND INTELLIGENCE OF THE SAMPLE

Subjects	Means	
	Chronological Age	Intelligence Quotient
Grade One (N = 20)	7.01	108.75
Grade Two (N = 20)	7.86	97.50
Grade Three (N = 20)	8.86	98.95
Grade Four (N = 20)	9.78	106.80
Grade Five (N = 20)	10.58	122.45
Grade Six (N = 20)	11.83	117.05
Total Sample (N = 120)	9.31	108.58

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TABLE II

MEAN SCORES FOR ITEMS 1 TO 4 OF SUBTEST I

WHEN PRESENTED IN A ROTATED ORIENTATION

Grade Level	Items			
	1	2	3	4
1	.55	.40	1.25	1.50
2	.80	.55	1.05	.80
3	.85	.60	1.35	1.65
4	1.70	.95	2.15	2.50
5	3.85	2.40	3.90	5.15
6	5.70	5.45	6.75	7.60

Note: Maximum possible score for each item = 8.00.

subtest when the cards were presented in a parallel orientation are given in table III.

Table III shows that with the exceptions of subjects in grades one and six, item 2 was once again found to be more difficult than item 1. Aside from this item, subjects in grades two to six inclusive found the items progressively easier but grade one subjects found item 3 to be easier than item 4. One explanation for this finding at the grade one level might be that since the children at this level did not appear to have a fully developed concept of a reference system utilizing artificial axes, the greater number of lines in item 4 (as compared to item 3) tended to confuse them with the result that fewer markers were placed accurately for this item than were for item 3. Subjects progressed through the items in an alternating order so that the effect of any learning might be controlled. However, a comparison of the scores of the subjects who performed the items in a 1, 2, 3, 4 order with the scores of the subjects who worked in an opposite manner revealed that there was no difference between them.

Results of Subtest II - Distance

Subtest II was designed to examine the subject's development of a concept of distance. It was comprised of five items each of which consisted of two, three-dimensional objects placed at an arbitrary distance from each other. These distances were, eleven and one half, sixteen and one half, thirty and one half, seven and

TABLE III

MEAN SCORES FOR ITEMS 1 TO 4 OF SUBTEST I

WHEN PRESENTED IN A PARALLEL ORIENTATION

Grade Level	Items			
	1	2	3	4
1	5.00	5.05	7.30	6.85
2	5.55	4.75	6.30	7.20
3	6.00	5.10	7.40	7.50
4	7.15	5.80	7.30	7.90
5	6.75	5.85	7.90	7.95
6	7.50	7.70	7.90	8.00

Note: Maximum possible score for each item = 8.00.

one-half, and twelve and one-half inches. The results of this subtest are presented in table IV. This table indicates that for the group as a whole, items 1 and 4 were easier than items 2, 3 and 5. It also shows that the grade six pupils scored higher than the pupils in grades one to five but that these scores fluctuate considerably.

Results of Subtest III - Natural Axes

This subtest was designed to determine the degree to which the subject had developed the concept of a reference system involving a natural axes system. There were nine items in this subtest each of which required the child to place an object in a specific location in one of four fields on a model farm. The results of this subtest are presented in table V.

An examination of table V reveals that the sample as a whole found items 1, 7 and 8 relatively easier than the other items and that item 4 was the most difficult. This generalization does not always hold true for every grade level, however, and many fluctuations in the scores may be observed. These results indicate that the total scores for the subtest increase with a rise in grade level.

Results of Subtest IV - Direction

Subtest IV was designed to test for the existence and state of development of the child's concept of direction. It contained

TABLE IV

RESULTS OF SUBTEST II - DISTANCE

Grade Level	Number of Correct Answers Per Item					
	Items					Total
	1	2	3	4	5	
1	9	8	7	13	5	42
2	6	6	7	9	7	35
3	10	7	6	12	4	39
4	12	6	7	7	8	40
5	15	10	7	10	11	53
6	17	9	10	15	9	60
Total	69	46	44	66	44	

Note: Maximum possible number of correct answers for each item at any grade level = 20.

TABLE V

RESULTS OF SUBTEST III - NATURAL AXES

Grade Level	Number of Correct Answers Per Item									
	Items									Total
	1	2	3	4	5	6	7	8	9	
1	25	23	20	5	16	13	22	25	13	162
2	22	22	21	14	15	18	20	20	15	165
3	26	21	23	17	27	19	26	23	19	201
4	31	30	24	23	18	24	27	27	19	223
5	30	20	25	25	24	23	28	29	22	226
6	32	27	30	30	29	28	28	30	27	261
Total	166	143	143	114	129	125	151	154	115	

Note: Maximum possible number of correct answers for each item = 40.

3 items. The results of this subtest are given in table VI.

This table indicates that the difficulty created by the three rotations of 180°, 90° and 270° was not equal for the group as a whole, but that the rotation of 180° was slightly easier than the other two. It is also apparent that the subject's ability to perform on this subtest increased with grade level.

<u>Results of Subtest V - Scale</u>

This subtest was designed to examine the state of development of the child's concept of scale. It contained five items. The results of this subtest, which are given in table VII, show that for the group as a whole, subjects were most adept at selecting the correct scale for item 2 (the circular granary) and item 4 (the oval lake). The total scores by grades indicate that the ability of this group of subjects to select the correct scale decreased from grade one to grade four and then rose sharply in grades five to six.

TABLE VI

RESULTS OF SUBTEST IV - DIRECTION

Grade Level	Number of Correct Answers Per Item			
	Items			
	1	2	3	Total
1	14	9	12	35
2	14	13	14	41
3	18	15	16	49
4	19	18	16	53
5	17	17	17	51
6	20	18	18	56
Total	102	90	93	

Note: Maximum possible number of correct answers per item by grade level = 20.

TABLE VII

RESULTS OF SUBTEST V - SCALE

Grade Level	Number of Correct Answers Per Item					
	Items					Total
	1	2	3	4	5	
1	4	15	5	8	1	33
2	2	14	5	9	1	31
3	2	14	2	11	1	30
4	4	10	3	8	3	28
5	6	14	6	13	5	44
6	13	12	9	14	10	58
Total	31	79	30	63	21	

Note: Maximum possible number of correct answers per item = 20.

II. OBSERVATIONS BASED ON THE TESTING SITUATION

Since the method which was followed in the testing situation was an adaptation of Piaget's "clinical" method of observation and interview, an effort was made to record those observations which might prove pertinent to an understanding of children's acquisitions of the concepts under investigation. Hence, the following observations of the manner in which subjects responded to the experiments were recorded.

Artificial Axes

Rotated Orientation. When the subjects at the grade one level were presented with the first four items in a rotated orientation, the following types of behaviour were observed. Eleven of the twenty children were completely unaware of the discrepancy of the relative positions of the pairs of cards. Consequently, the need to turn one of the cards was not taken into account and these subjects placed their markers in a replication of the pattern as if the latter had simply been superimposed over the blank card and with no change in its orientation.[16] Of the seven individuals who evidenced some awareness of the need to rotate the cards, only two could do so correctly for all four items. Three subjects indicated an awareness of the need for

[16] Hereafter this method of replicating a pattern of markers shall be termed "direct transfer."

rotation immediately but were unable to place even one marker correctly. Of the remaining two subjects who did rotate, one did not become aware of this need until item 3 and the other not until item 4. In addition, it was noted that those subjects who were aware of the need, but who could not rotate, were often confused by the lines in items 3 and 4. Where this happened, one segment was rotated correctly but the others were simply copied using direct transfer. Another interesting observation was that seven subjects made reflected or mirror images of part of the patterns.

A similar type of behaviour was observed with subjects at the grade two level where again only four individuals completed any item correctly. A total of fifteen subjects realized that the cards should be brought into alignment but eleven of them could not cope with the problem and three pupils did not recognize this need until they tried item 4.

One child mentally rotated the card for item 3 (single axes) correctly but could not place a single marker correctly for item 4 (double axes). As he himself explained, "it's too hard with all these lines. They mix you up." One of the most common difficulties observed at this grade level involved the children's tendencies to become confused and use both mirror images and direct transfer on one card in an attempt to copy a pattern.

At the grade three level seventeen of the twenty subjects realized the need for rotation but only nine could place markers

accurately. Again some subjects only became aware of the need when confronted with items 3 or 4 (the cards with axes on them). In addition, there were three cases of confusion of mirror images with a direct transfer of the patterns.

Seventeen out of twenty children at the grade four level realized the need for rotation but only ten could place markers correctly. While the numbers of subjects who realized the need for rotation was the same in grades three and four, the grade four subjects were much more expert at replicating the patterns. Six of the ten who could place the chips correctly did so on all four items. Only two grade three pupils completed all four items. Also at this level the children were able to explain their actions and why some pairs of cards were easier than others. One child, when asked which pair was the easiest replied, "This one (item 4) is easier because it has more lines on it." Often, when the child became confused it was due to his use of both mirror images and direct transfer in copying a pattern of markers. Again this was most frequent in items 3 and 4 where the subject would rotate one or two segments correctly and then use a mirror image or direct transfer for the others.

Only two subjects at the grade five level evidenced no awareness of the need for rotation, all of the others either placed markers correctly or indicated that they realized that the two cards should be aligned. This particular subtest appeared to be extremely difficult for the grade five children. These subjects

became very frustrated by their inability to mentally rotate the cards immediately and it took them twice as long as any of the others to perform the tasks. Fewer mirror images were encountered in this group as compared to the previous four grades, however, in a number of cases the subject began to copy the pattern in an unrotated manner, stopped and corrected himself and then became so confused he was unable to continue.

The reason the rotation of the cards confused so many children up to this point was possibly illustrated by those subjects who used their fingers to gauge the distance between the lines or edges of a card and each marker. In every case up to the grade five level whenever this type of manual transfer was employed, the subjects measured in <u>one</u> direction only and did not seem to be aware of the need to measure in both directions.

At the grade six level every subject immediately recognized the need to rotate one of the pairs of cards and was able to do so correctly. The ability of some of these subjects to understand how coordinate axes could be used as a reference system was indicated by one who explained, "You can use the angles of the lines to tell where it [the marker] should go."

It would appear from these observations that very few children in grades one and two were aware of the differences in the orientation of the pairs of cards but that this awareness increased as the grade level rose until at the grade six level all children realized the need for rotation. It was also apparent that an

awareness of this need was no indication of the child's ability to perform the rotation even at the grade five level.

Parallel Orientation. When the pairs of cards were presented to the subjects in a parallel orientation, that is, with both cards in alignment, the following observations were noted.

At the grade one level all of the subjects were able to correctly place some markers for each of the four items. It was noted that the children seemed to find item 3 (single axes) easier than the previous two items and item 4 (double axes) easier still. The scores for these items substantiated this observation. Some children had trouble with items 3 and 4 and apparently found that the lines confused rather than aided them. One subject used a mirror image of the pattern for all four items and when questioned, maintained that his cards looked exactly like the cards from which he had copied the patterns. Two children used mirror images for items 1 and 2 and then changed to a direct transfer technique for items 3 and 4.

From the grade two level up to and including grade six, no cases were observed where the children had difficulties with any of the items. The occurrence of some mirror images was noted up to the grade four level but they did not occur past this point.

The performance of one grade three boy was especially interesting. This subject completed all four items in an almost perfect manner, yet when he copied each pattern he did so by means of a double transformation. That is, he made a mirror

image of it while at the same time rotating it through an angle of 180^{o}. Despite the changes this double transformation made in the orientation of the patterns, this subject was not aware of these changes. In fact, when asked whether his cards looked like the ones he had copied, the subject maintained that they were exact replicas and had not been altered in any way.

It was also noted that the majority of subjects at all grade levels took little notice of the orientation of the marker with the axes drawn on it which appeared in item 2. Even when the marker was located correctly very few children attempted to turn it the same way as it appeared in the original pattern. This held true for both the rotated and the parallel orientation of the cards.

It would appear from these observations that while the rotation of one of each pair of cards introduced another factor into the situation, this factor clearly indicated whether the subjects had a concept of a reference system using coordinate axes or not. When the cards were perfectly aligned and parallel to the child, the subject was able to copy the patterns with relatively little trouble and it was not clear whether he was using a reference system or not, even though there were markedly better performances on items 3 and 4, which had axes on them. This was probably due to the fact that since the cards were perfectly aligned and close together, a measurement (either manual or mental) in one direction only permitted the child to place his markers on the blank card with considerable accuracy. This is not to say that the axes

systems on items 3 and 4 did not aid the subject but it could be that these lines were used quite unconsciously and as a guide in just one direction. However, when the situation required the child to take the rotation of one spatial field into account, he had to measure along both axes, that is, in <u>two</u> directions, if he was to place the markers correctly on the blank card. Thus, by noting the degree of success a subject attained when called upon to copy a pattern from a rotated card, one might interpret the results as indicative of the degree to which that subject had developed and could use the concept of a reference system incorporating an orthogonal axes system.

With one or two notable exceptions these results compare favorably with those described by Piaget in his experiments on the development of general systems of reference. According to Piaget, the tests he used were ineffectual at the Stage I level (for which no ages are given) while at the Stage II level (ages between six years two months to seven years two months), the children are preoccupied with purely perceptual features in trying to copy the patterns. That is, they do not attempt to make use of a reference system and for Piaget's sample, they do not understand how to apply such a system even when shown how it may be used.

In this study the majority of the children in grades one, two and three appeared to be at this stage of development as they too did not use the axes systems provided. Thus, the same stage was observed, but the ages at which it occurred differed from

those listed by Piaget. For this sample, children as old as nine years could be classified as belonging to Stage II while according to Piaget, this stage should end at approximately age seven.

Piaget describes Stage III as lasting from approximately eight years three months to nine years one month and claims it is distinguished by the childrens' beginning use of references separate from the parts of the figure. In his sample, subjects at this level could apply qualitative comparisons of the position and orientation of the markers but could not coordinate their relative distances and true positions in an overall way. Examples of this type of behaviour were also found in the sample used in this study. In the latter, children were seen to rotate one or two segments of a pattern or to apply manual measurements in one direction, but they could not place all of the markers correctly for all the items. As was the case for Stage II, the ages for this third stage were found to be later than Piaget's and appeared to be approximately ten to eleven years.

The fourth stage Piaget describes occurs after the age of eleven or twelve which is the stage of formal operations of thought. It is only at this stage, says Piaget, that true conventional reference systems are developed and the child can compare positions and distances simultaneously. This stage was also found in the present study and included the majority of the grade five subjects and all of the grade six children. This group appeared to be fully aware of the use of the coordinate axes on the cards and used

them to good advantage. Examples were also noted of children who used manual transfer to measure distances in two directions. This would indicate that these subjects could now compare the positions and distances. In this case the ages found for Stage IV compare favorably with those listed by Piaget. He states that this stage appears after eleven or twelve and the findings of this study indicate that the ages for this sample ranged from eleven years three months to twelve years seven months.

Distance

At the grade one level, subjects were unable to explain how they judged the distances between the pairs of objects and appeared to use only visual estimations. Some subjects in grade two tried to apply manual transfer to the distances by placing a finger beside each of the objects; of course, as soon as the subject reached out to pick up the objects this measurement was lost. A few subjects in grade three explained that they thought of the distances in terms of certain units but these were seldom the standard units of inches and feet. One subject estimated the distances in terms of so many "fingers" wide and another in terms of things "about this long," indicating a space between two fingers.

Subjects at the grade four level often applied manual transfer to the distances and some "walked off" each distance with their fingers. One subject explained that she tried to use the edges of the table as reference points but lost her place when the

objects were moved. Starting at the grade five level and continuing with the grade six pupils, subjects were often observed to "step off" the distances with their fingers, or to apply the length of their arm to the space between objects. At this point a common explanation of the method used for estimating the distances was that the child thought of the latter in terms of so many inches. The occurrence of these methods for judging distances is approximately the same as the pattern discovered by Piaget. In general, the subjects began with visual estimation alone, progressed to some form of manual transfer and then arrived at a stage where a type of unit iteration was applied. From the varying degrees of success as shown by the sample, the investigator was led to conclude that regardless of the method used to judge these distances, this sample of children was not able to judge relatively small distances accurately.

Natural Axes

Children at the grade one level evidenced a great deal of surprise when the model was rotated and took a relatively long period of time to decide in which field the object should be placed. Many of the children were reluctant to place the object without taking a second look at the first (unrotated) model. One subject disregarded the rotation of the model and placed all the objects relative to his own position. Most of these subjects seemed content to merely find the correct field and few made any

attempt to place the objects in the correct locations in the fields.

The grade two children displayed the same type of responses but seemed to be more aware of the necessity of placing the objects in the correct locations within the fields. As one subject expressed it, "He goes in this field but I can't tell where." Again the rotation of the model confused a great many with the result that few were able to locate the correct field for every item. Two subjects completely disregarded the rotation of the model and placed every object relative to their own position. Another subject seemed to be aware of the possibility of using objects as reference points and used his fingers to measure the distance between an object already on the model and the place where the new object should be located. It was noticed, however, that this manual measurement was always taken in one direction only. Subjects at the grade three level had fewer problems in locating the correct field but there was still one case of a child who made no attempt to account for the rotation of the model in placing his objects. While another subject insisted that he could not place any object on the rotated model unless he was permitted to walk around it until he was standing at it as if it were unrotated.

Grade four subjects obtained higher scores on this subtest than the grade three subjects and every child tried to account for the rotation of the model although some children had more trouble with this factor than did others. One subject became quite exasperated during the test and told the examiner, "I can't find

where it goes if you keep turning it!" The first appearance of measurement in two directions occurred at this grade level with a subject who used his fingers to take two measurements for the placement of each object. Nevertheless, this child did not always transfer these measurements onto the rotated model in the correct way. That is, when applying the measurements to the rotated model, the two directions were often reversed (due to the rotation) and the object was not located accurately.

When subjects at the grade five and six levels were questioned as to how they knew where to place the objects, every child gave some indication that he or she used the fixed objects as reference points, only one subject used manual measurement and these were in one direction only. All other subjects seemed to rely on visual estimation alone in one or two directions.

By using these observations, it was possible to identify the three stages of development Piaget claims to have found in his experiment with a natural axes system. However, the ages at which these stages occurred did not always agree with those listed by him. For instance, Piaget claims that throughout Stage I (up to approximately three and one half or four years), the positions are located primarily through topological relationships of proximity, that is, the child ignores the rotation of the second model and either places the object in any field or else places it in a field to correspond to the first model but disregards the fact that the model he is now working at has been turned. In the sample used in

this study there were four instances of children well past the age of four years who, according to Piaget's terms, were still at Stage I. These children were unable to place even one object correctly due to the fact that they completely ignored the rotation of the second model and placed their objects relative to their own positions. The ages of these subjects were six years ten months, seven years five months, seven years ten months and nine years six months. Their respective intelligence quotients were eighty-nine, eighty-three, one hundred two, and seventy-seven.

The low intelligence quotients of three of these subjects might explain why they are still in Stage I but this would not apply to the subject with an intelligence quotient of 102.

A similar finding was observed with regards to Stage II. According to Piaget, this stage occurs between the ages of four to seven and is marked by the child's growing ability to take rotation into account. Thus children at this stage may initially place the object incorrectly but are capable of realizing their error and can rectify it. However, in this study a great many children over the age of seven could not take the effect of rotation into account and correctly locate each object every time. In fact, some subjects as old as ten years eight months and eleven years six months could not locate the correct field for one or more of the objects.

Stage III, as described by Piaget begins at approximately six and one half or seven years and is distinguished by the complete mastery over all the relationships so that all the objects are correctly

located. In Piaget's sample every child over the age of eight years could determine every position accurately. In this sample no child could place every object correctly. Even at the grade six level subjects missed an average of two objects out of the total of nine. However, it might also be that the addition of two more rotations to this subtest (90^o and 270^o) made it more difficult than the test used by Piaget.

It would appear from these findings that while the general pattern of development as described by Piaget does exist, the ages he gives for these stages do not apply to this sample and that these stages take much longer to develop for the latter group.

Direction

Observation of the subjects during the subtest on direction revealed a general pattern of the manner in which subjects performed. However, due to the occurrence of two or more of these stages at each age and grade level it was impossible to define these stages in terms of chronological age. The pattern of development appeared to be as follows. In Stage I, the children do not use objects as reference points and do not take into account the fact that the model is rotated. Subjects at this level did not place the truck in front of the shed each time and consequently did not start from the correct place. Examples of this type of behaviour were found in grades one, two, three and five. In Stage II, children have some concept of a reference system and can use objects as reference points. They also take the rotation of the model into account. Children at this level always started at the correct point, and could indicate the correct direction. These children were seldom confused by the rotation of the model. After the subtest was completed the subjects

were asked to explain how they knew which direction to turn; typical replies for Stage II were: "Well, he starts here at the shed and drives to the roads and then he turns at the tree."
Subject: "You have to start here (pointing to shed) and then you go along here and turn like this (indicating a right turn)."
Examiner: "But how did you know which way to turn?"
Subject: "Well, there's a tractor over in that field and he doesn't drive by it and he doesn't go straight ahead so he has to go this way [right]." Examples of this stage were found from the grade one level up to and including the grade six pupils.

In the final stage, Stage III, the pupils use a reference system of objects but no longer consciously consider them as separate entities. Subjects at this stage explain their actions in terms of what Piaget would call a schema since the action is now fully internalized mentally and exists as a kind of a formula which is not necessarily linked with particular objects. When subjects at this stage were asked to explain how they knew which direction to go to get to town, a common response was to look at the examiner as if he was quite foolish to ask such a simple question and then to reply simply, "He starts off and turns right" or merely "you go right." The majority of grade five and grade six pupils appeared to be at this stage.

Scale

When the subjects were confronted with the subtest on scale, many children responded in similar ways which gave rise to a general

pattern in the observations. If these observations were used to classify the children into certain developmental stages in a Piagetian manner, they could be explained as follows:

Subjects at the Stage I level appeared to have little or no concept of scale and simply chose from among the symbols at random, or they chose the first symbol (or second, or third, etcetera) on every card. There was very little possibility that the instructions were not understood in these or any other cases since each subject was given a practice item before the test began. This practice item consisted of selecting one of three sizes of roads and actually placing it on the smaller map. Every child in the sample chose the correct road, some after a series of trials and errors, but there is little doubt that the children knew what was expected of them.

The second type of response (which might be called Stage II), was marked by the child's growing awareness of the concept of scale although the concept could not be applied. Children at this level of development repeatedly chose the symbol which was the same size as the symbol on the larger map. Another type of response which might also be classified as occurring within this level, was exhibited by subjects who recognized the symbol that was the same scale as the symbol on the large map and at the same time realized that this symbol would not be appropriate for the smaller map. Subjects of this type frequently picked any other symbol on the card or the symbol beside the one which was correct for the large map.

Examples of both these stages were observed up to and including the grade four level with no one type of response predominating in any one grade level.

The scores and the manner in which subjects selected the symbols improved greatly at the grade five and six level which might be interpreted as the appearance of a third and final stage in the development of this concept. Children at this level of development appeared to be quite aware of the necessity of selecting symbols which would all be the correct size for the smaller map. One common type of behaviour was for the child to use his fingers to measure the symbol on the large map to transfer this measurement to the small map, adjust it so it would fit and then to transfer this new measurement to the card of symbols where the child tried to match it up with one of the symbols. Subjects were observed to take manual measurements in this manner in both one and two-dimensions. Other subjects seemed to follow the same type of procedure but relied solely on visual estimation. At least two of the subjects in grade six had some knowledge of the concept of scale. One asked the examiner what ratio existed between the large and small maps while the other asked what the scale was for the two maps.

Since the acquisition of the concept of scale (as measured by this test) occurred so suddenly and at the grade five and six level where more advanced map work and mathematics are being taught, it would be reasonable to assume that school experience

may be one of the most important factors in the development of this concept. With the exception of the fact that this concept does not appear as early as Piaget claims, these findings are in close agreement with his findings. Piaget found that the concept of scale appeared at approximately the age of nine to ten years but was not fully understood until the level of formal operations or the ages of eleven to thirteen. For this sample, the concept begins to appear at age ten or eleven, and there are few instances of its being fully understood by age twelve. For both this sample and that of Piaget, the effect of schooling is probably very influential in the acquistion of the concept.

III. THE STATISTICAL ANALYSES OF THE RESULTS

An Analysis of the Subtests and Items

In this section, the correlations between the items comprising each subtest will be examined and discussed.

Artificial Axes System. All of the eight items which comprised the subtest on artificial axes systems were analyzed by determining the Pearson product-moment correlation coefficient for each item with every other item. Intercorrelations were found for each of the four items when used in a rotated orientation and for each of the four items when used in a parallel orientation. These intercorrelations are presented in tables VIII and IX.

A study of table VIII indicates that each of the four items

is significantly and highly correlated with each of the others at the .01 level of significance. This level of significance may be interpreted as meaning that the probability of this correlation occurring by change alone is one in one hundred. This would indicate that each of these four items in this subtest was measuring the same thing.

An examination of table IX reveals that all items are significantly correlated with the others with the exception of the intercorrelations between items 1 and 3 and 3 and 4. However, items 1 and 3 do correlate at the .05 level of significance and the .001 intercorrelation of items 3 and 4 occurred due to the fact that the scores on these two items were so similar that there was a very narrow range of scores. This resulted in a correlation which appears to be considerably less than significant, but which in actual fact is an extremely high intercorrelation. Thus, it may be stated that each of the items in this section of the subtest was also measuring the same factor.

Distance. The tetrachoric correlation coefficients for the intercorrelations of the five items used in subtest II, the test on distance, are presented in table X.

This table shows that none of the five items used in the subtest on distance is significantly correlated to any of the others. This would indicate that each of these items is entirely independent of the others. This could also be interpreted as meaning that every time a subject was presented with one of these

TABLE VIII

INTERCORRELATIONS OF EACH OF THE FOUR ITEMS IN SUBTEST I

WHEN USED IN A ROTATED ORIENTATION

Item	Items			
	1	2	3	4
1	1.000	.788*	.740*	.757*
2		1.000	.672*	.730*
3			1.000	.888*
4				1.000

*Significant at the .01 level ($r \geq .254$).

TABLE IX

INTERCORRELATIONS OF EACH OF THE FOUR ITEMS IN SUBTEST I

WHEN USED IN A PARALLEL ORIENTATION

Item	Items			
	1	2	3	4
1	1.000	.427*	.195	.258*
2		1.000	.374*	.294*
3			1.000	.001
4				1.000

*Significant at the .01 level ($r \geq .254$).

TABLE X

INTERCORRELATIONS OF EACH OF THE FIVE ITEMS USED IN SUBTEST II,

DISTANCE

Items	Items				
	1	2	3	4	5
1	1.000	.064	- .188	.110	0.64
2		1.000	.030	.098	.007
3			1.000	.046	.089
4				1.000	.014
5					1.000

Note: r = .254 at the .01 level of significance.

items it was viewed as a completely new situation which had little in common with the other items in the subtest.

Natural Axes. Pearson product-moment correlations were also calculated for the interrelationships of each of the nine items in subtest III. These intercorrelations are presented in table XI.

An examination of table XI reveals that each of the nine items correlates positively and significantly with at least one other item in the subtest and that some items (numbers six and eight) intercorrelate with five other items. This may be interpreted as meaning that every item in this subtest is measuring something in common with one or more of the other items which comprised the test.

Direction. The next table, table XII, shows the intercorrelations between the three items which were used in subtest IV, the subtest on direction. These correlations were calculated as tetrachoric correlation coefficients.

A study of table XII reveals that each of the three items in subtest IV is positively and significantly correlated with every other item in the subtest. This indicates that all three items measure a common factor.

Scale. The intercorrelations between the five items used in subtest V are presented in table XIII. This subtest was the subtest on scale.

Table XIII, indicates that items 1, 3 and 5 are significantly correlated at the .01 level of significance while items 2 and 4 do

TABLE XI

INTERCORRELATIONS OF EACH OF THE NINE ITEMS USED IN SUBTEST III, NATURAL AXES

Items	Items								
	1	2	3	4	5	6	7	8	9
1	1.000	.304*	.149	.257*	.243	.214	.213	.353*	.113
2		1.000	.365*	.059	.123	.316*	.214	.236	.091
3			1.000	.234	.070	.426*	.246	.354*	.237
4				1.000	.192	.406*	.181	.310*	.420*
5					1.000	.215	.294*	.161	.182
6						1.000	.265*	.253	.274*
7							1.000	.383*	.258*
8								1.000	.296*
9									1.000

*Significant at the .01 level ($r \geqq .254$).

TABLE XII

INTERCORRELATIONS OF EACH OF THE THREE ITEMS USED IN SUBTEST IV,

DIRECTION

Items	Items		
	1	2	3
1	1.000	.916*	.777*
2		1.000	.906*
3			1.000

*Significant at the .01 level ($r \geqq .254$).

TABLE XIII

INTERCORRELATIONS OF EACH OF THE FIVE ITEMS USED IN SUBTEST V, SCALE

Items	Items				
	1	2	3	4	5
1	1.000	.000	.622*	- .122	.067
2		1.000	- .077	- .059	- .448*
3			1.000	- .191	.836*
4				1.000	- .093
5					1.000

*Significant at the .01 level ($r \geq .254$).

not appear to correlate positively with any of the other items. Item 2, however, does have a significant negative correlation with item 5. These intercorrelations may be interpreted as meaning that items 1, 3, and 5 measured some common factor while items 2 and 4 measured independent factors. An examination of the items further serves to explain these findings. Items 1, 3 and 5 were each rectangular in shape and according to these intercorrelations, if a child could select the correct size (scale) for one of these shapes, it was probable that he could select the correct size for the other two. However, in the case of items 2 and 4 the shapes were a circle and an oval and the child's ability to choose the correct size for one shape had no bearing on his ability to do this for the other shape. The negative, but significant correlation between items 2 and 5 may be interpreted as meaning that the more likely a child was to choose the correct size for item 2, the less likely he was to choose the correct size for item 5 or visa versa.

An Analysis of the Results in Terms of the Research Hypotheses

This section will present the results of the study together with the statistical procedures which were applied to determine the relationship of the former with such factors as sex, intelligence, socio-economic status, age and grade level.

Hypothesis 1. There is no significant correlation between sex and the development of the concepts of a reference system,

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distance, direction and scale. In order to test this hypothesis the intercorrelations between each subject's sex and his or her scores on the five subtests were calculated using biserial correlation coefficients. These correlations are presented in table XIV.

A study of table XIV reveals that there is no significant correlation at the .01 level of significance between sex and any of the concepts under investigation. Therefore, this hypothesis was accepted.

Hypothesis 2. There is no significant correlation between socio-economic status and the development of concepts of a reference system, distance, direction and scale. This hypothesis was tested by calculating the intercorrelations between each subject's socio-economic status and his or her scores and the five subtests. The resultant biserial correlation coefficients are presented in table XV.

A study of this table reveals that socio-economic status is not significantly related at the .01 level of significance with the development of any of the concepts under investigation. Consequently, this hypothesis was accepted.

Hypothesis 3. There is no significant correlation between chronological age and the development of concepts of a reference system, distance, direction and scale. This hypothesis was tested by determining the intercorrelations between the chronological ages of the subjects and their scores in the five subtests. These correlations are presented in table XVI.

TABLE XIV

CORRELATIONS OF THE FIVE TEST SCORES WITH SEX

Subtest		Correlation With Sex
I	Artificial Axes	.026
II	Distance	.155
III	Natural Axes	-.026
IV	Direction	.089
V	Scale	.045

Note: $r \geqq .254$ at the .01 level of significance.

TABLE XV

CORRELATIONS OF THE FIVE SUBTEST SCORES WITH SOCIO-ECONOMIC STATUS

	Subtest	Correlation With Socio-Economic Status
I	Artificial Axes	.028
II	Distance	-.005
III	Natural Axes	.031
IV	Direction	.072
V	Scale	.050

Note: $r \geqq .254$ at the .01 level of significance.

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TABLE XVI

CORRELATIONS OF THE FIVE SUBTEST SCORES WITH CHRONOLOGICAL AGE

	Subtest	Correlation With Chronological Age
I	Artificial Axes	.662*
II	Distance	.358*
III	Natural Axes	.470*
IV	Direction	.295*
V	Scale	.275*

*Significant at the .01 level ($r \geqq .254$).

Table XVI shows that chronological age is significantly correlated at the .01 level of significance with the concepts under investigation. Consequently, this hypothesis was rejected.

Hypothesis 4. There is no significant correlation between intelligence and the development of the concepts of a reference system, distance, direction and scale. This hypothesis was tested by calculating the intercorrelations between the measures of the subjects' intelligence (Lorge-Thorndike IQ scores) and their scores on the five subtests. These correlations are presented in table XVII.

Table XVII shows that intelligence is significantly correlated at the .01 level of significance with the development of concepts of reference system utilizing artificial axes, a reference system utilizing natural axes, direction and scale. However, intelligence is not significantly correlated with the development of a concept of distance. As a result, this hypothesis was rejected for the concepts of a reference system, direction and scale, but accepted in the case of the development of a concept of distance.

Hypothesis 5. There is no significant correlation between grade level and the development of concepts of a reference system, distance, direction and scale. This hypothesis was tested by calculating the intercorrelations between the subject's grade levels and their scores on the five subtests. These correlations are presented in table XVIII.

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TABLE XVII

CORRELATIONS OF THE FIVE SUBTEST SCORES WITH INTELLIGENCE

	Subtest	Correlation With Intelligence
I	Artificial Axes	.519*
II	Distance	.186
III	Natural Axes	.436*
IV	Direction	.319*
V	Scale	.284*

*Significant at the .01 level ($r \geqq .254$).

TABLE XVIII

CORRELATIONS OF THE FIVE SUBTEST SCORES WITH GRADE LEVEL

	Subtest	Correlation With Grade Level
I	Artificial Axes	.661*
II	Distance	.336*
III	Natural Axes	.485*
IV	Direction	.328*
V	Scale	.356*

*Significant at the .01 level ($r \geqq .254$).

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[illegible]	[illegible]
[illegible]	[illegible]

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This table shows that grade level is significantly correlated at the .01 level of significance with the development of all the concepts under investigation. Therefore, this hypothesis was rejected.

A possible explanation of the lack of correlation between intelligence and the results of the subtest on distance might be that accuracy on these test items was more dependent upon a visual memory factor than on intelligence. Consequently, those subjects who could mentally retain the visual estimation they had noted before the objects were moved could replace the objects with the required distance between them regardless of their intelligence.

It should also be noted that while intelligence correlates with the results of the battery of tests, socio-economic status does not. Yet intelligence and socio-economic status are considered to be highly related. The reasons for this apparent discrepancy may lie in the method used to classify pupils as to their social class membership. By selecting the median in Blishen's fourth category as an arbitrary point to divide the pupils into high or low socio-economic groups, a large number of pupils who belonged to the middle categories were assigned to one of the two classifications. This may have tended to equalize the two categories to the point where the differences between the two groups were minimized. If a division of the subjects had been made including only those pupils who belonged to the two extremes of Blishen's scale the results might have been different.

Additional Analysis

Even though the effect of sex for the total sample was not found to be significant in the development of any of the concepts under investigation, there was a possibility that subject's scores within a grade level might vary according to their sex. Consequently, it was decided to apply a statistical procedure to determine whether children's scores on the five subtests might vary by sex within the grades. In order to avoid confusing the question by an inclusion of the factor of intelligence, the latter was to be held constant. The statistical procedure selected was a two-way analysis of covariance. This form of analysis was applied to each of the five subtests and the results of the analysis are presented in table XIX to XXIII inclusive.

An examination of table XIX reveals that the adjusted F-ratio (0.00) associated with comparisons between the means of the sexes did not exceed the critical F-ratio (6.90). Consequently, the differences between the sexes in any one grade in terms of their knowledge of the concept of reference system utilizing an artificial axes system were not statistically significant. There were significant differences between the mean scores of the subjects according to grade level as one might expect. The interaction effect was not statistically significant.

Tables XX to XXIII inclusive reveal similar results in which the adjusted F-ratios associated with comparisons between the means of the sexes did not exceed the critical F-ratio.

TABLE XIX

SUMMARY OF ANALYSIS OF COVARIANCE: SCORES OF SUBTEST I

ADJUSTED FOR THE EFFECT OF INTELLIGENCE

Source	SS	df	MS	F
Sex	0.41	1	0.41	0.00
Grade	7572.77	5	1514.55	15.47*
Sex by Grade (interaction)	380.41	5	76.08	0.78
Within (error)	10478.34	107	97.93	

*Significant at the .01 level

$F\ (1,107)_{.01} = 6.90$ $F\ (5,107)_{.01} = 3.20$

TABLE XX

SUMMARY OF ANALYSIS OF COVARIANCE: SCORES OF SUBTEST II

ADJUSTED FOR THE EFFECT OF INTELLIGENCE

Source	SS	df	MS	F
Sex	3.77	1	3.77	3.32
Grade	19.59	5	3.94	3.45*
Sex by Grade (interaction)	1.63	5	0.34	0.29
Within (error)	121.57	107	1.14	

*Significant at the .01 level

$F(1,107)_{.01} = 6.90$ $F(5,107)_{.01} = 3.20$

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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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TABLE XXI

SUMMARY OF ANALYSIS OF COVARIANCE: SCORES OF SUBTEST III

ADJUSTED FOR THE EFFECT OF INTELLIGENCE

Source	SS	df	MS	F
Sex	4.42	1	4.42	0.52
Grade	222.22	5	44.44	5.21*
Sex by Grade (interaction)	56.30	5	11.26	1.32
Within (error)	913.33	107	8.53	

*Significant at the .01 level

$F\ (1,107)_{.01} = 6.90$ $F\ (5,107)_{.01} = 3.20$

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[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]
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TABLE XXII

SUMMARY OF ANALYSIS OF COVARIANCE: SCORES OF SUBTEST IV

ADJUSTED FOR THE EFFECT OF INTELLIGENCE

Source	SS	df	MS	F
Sex	0.52	1	0.52	0.56
Grade	13.16	5	2.63	2.84
Sex by Grade (interaction)	2.02	5	0.40	0.44
Within (error)	99.26	107	0.93	

$F\ (1,107)_{.01} = 6.90$ $\quad$ $F\ (5,107)_{.01} = 3.20$

TABLE XXIII

SUMMARY OF ANALYSIS OF COVARIANCE: SCORES OF SUBTEST V

ADJUSTED FOR THE EFFECT OF INTELLIGENCE

Source	SS	df	MS	F
Sex	0.20	1	0.20	0.20
Grade	22.82	5	4.56	4.47*
Sex by Grade (interaction)	3.58	5	0.71	0.70
Within (error)	109.33	107	1.02	

*Significant at the .01 level

$F\,(1,107)_{.01} = 6.90$ $F\,(5,107)_{.01} = 3.20$

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[illegible]	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]

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Hence, these tables show that the difference between the sexes in any one grade level in terms of their knowledge of any of the concepts under investigation were not statistically significant. With the exception of the subtest on direction, there were significant differences between the mean scores of the subjects according to grade level as would be expected. In the case of the subtest on direction, since the mean differences between grade levels were not significant when intelligence was held constant, one might conclude that intelligence is one of the most important factors in the development of this concept.

Since the correlation of grade level with the attainment of the spatial concepts under investigation proved to be significant, it was decided to examine this relationship more closely. Hence, the means and standard deviations for each subtest score for each grade level were calculated. These means and standard deviations are presented in table XXIV. An examination of this table reveals that for each subtest, the general trend is for an increase in scores with the rise in grade level. There are, however, several variations in these trends. In order that the relationship between these mean scores and grade levels might be rendered more meaningful, the means for each subtest have been plotted by grades and are shown in figures 15 to 20 inclusive.

TABLE XXIV

MEANS AND STANDARD DEVIATIONS OF EACH SUBTEST ACCORDING TO GRADE

Subtest	Means By Grade Level						Standard Deviations By Grade Level					
	1	2	3	4	5	6	1	2	3	4	5	6
I (64)	27.90	27.75	30.45	35.40	43.50	56.75	9.44	10.08	9.77	10.21	14.02	5.47
II (5)	2.05	1.75	1.95	2.00	2.65	3.05	1.02	0.94	0.97	1.05	0.96	1.20
III (18)	8.10	8.35	10.20	11.15	11.40	13.05	2.74	3.65	3.52	2.76	3.01	2.44
IV (3)	1.75	2.05	2.45	2.65	2.55	2.80	1.30	1.07	0.92	0.79	0.97	0.60
V (5)	1.65	1.55	1.50	1.40	2.20	2.90	0.79	0.97	0.87	1.02	0.98	1.18

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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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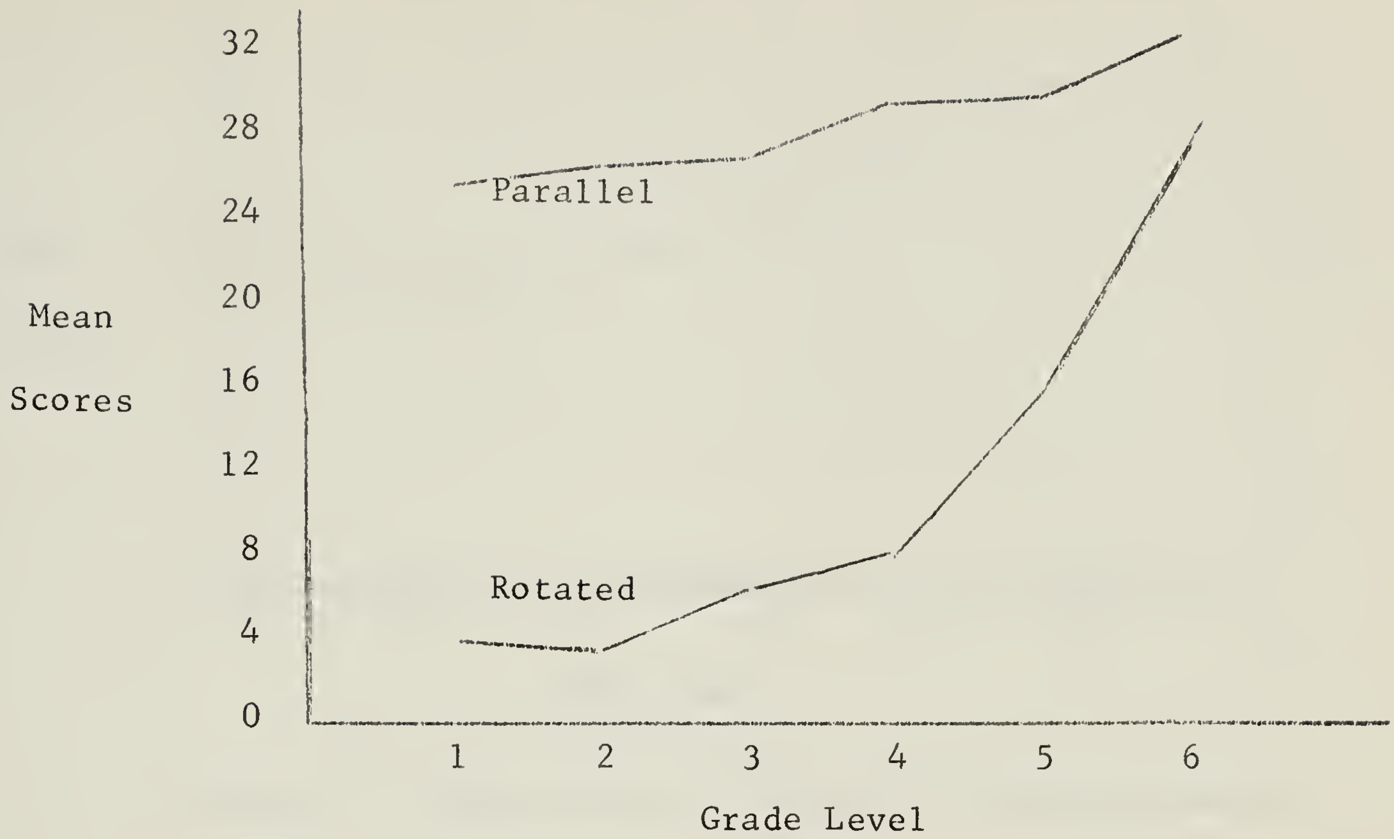

Figure 15. Mean Scores of Subtest I by Grade Level.

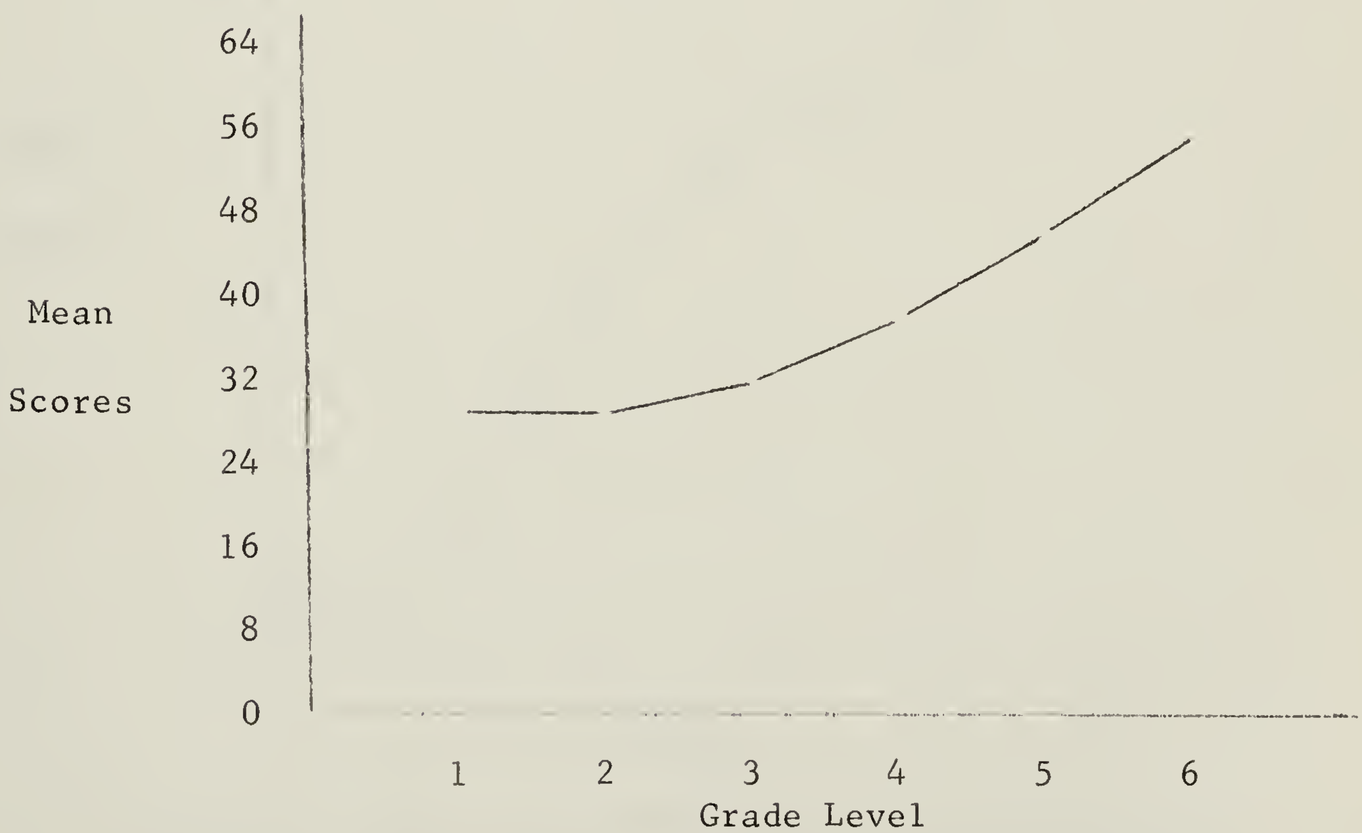

Figure 16. Combined Mean Scores of Subtest I by Grade Level.

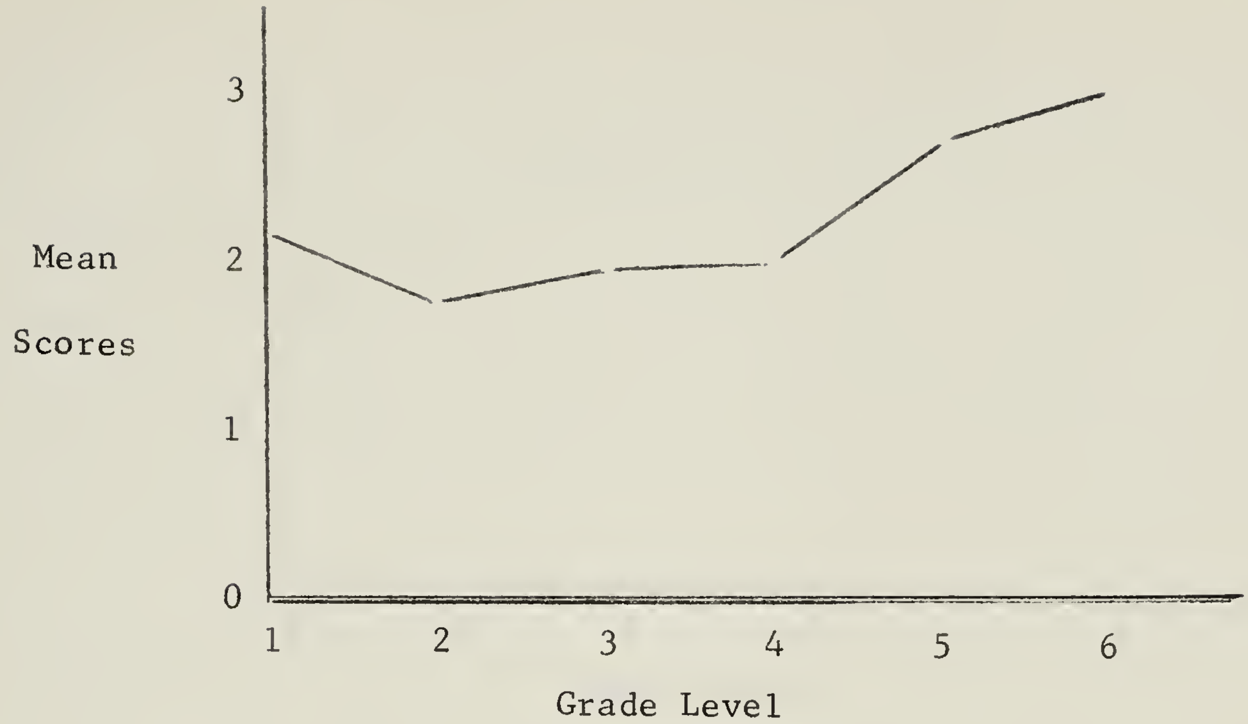

Figure 17. Mean Scores of Subtest II by Grade Level

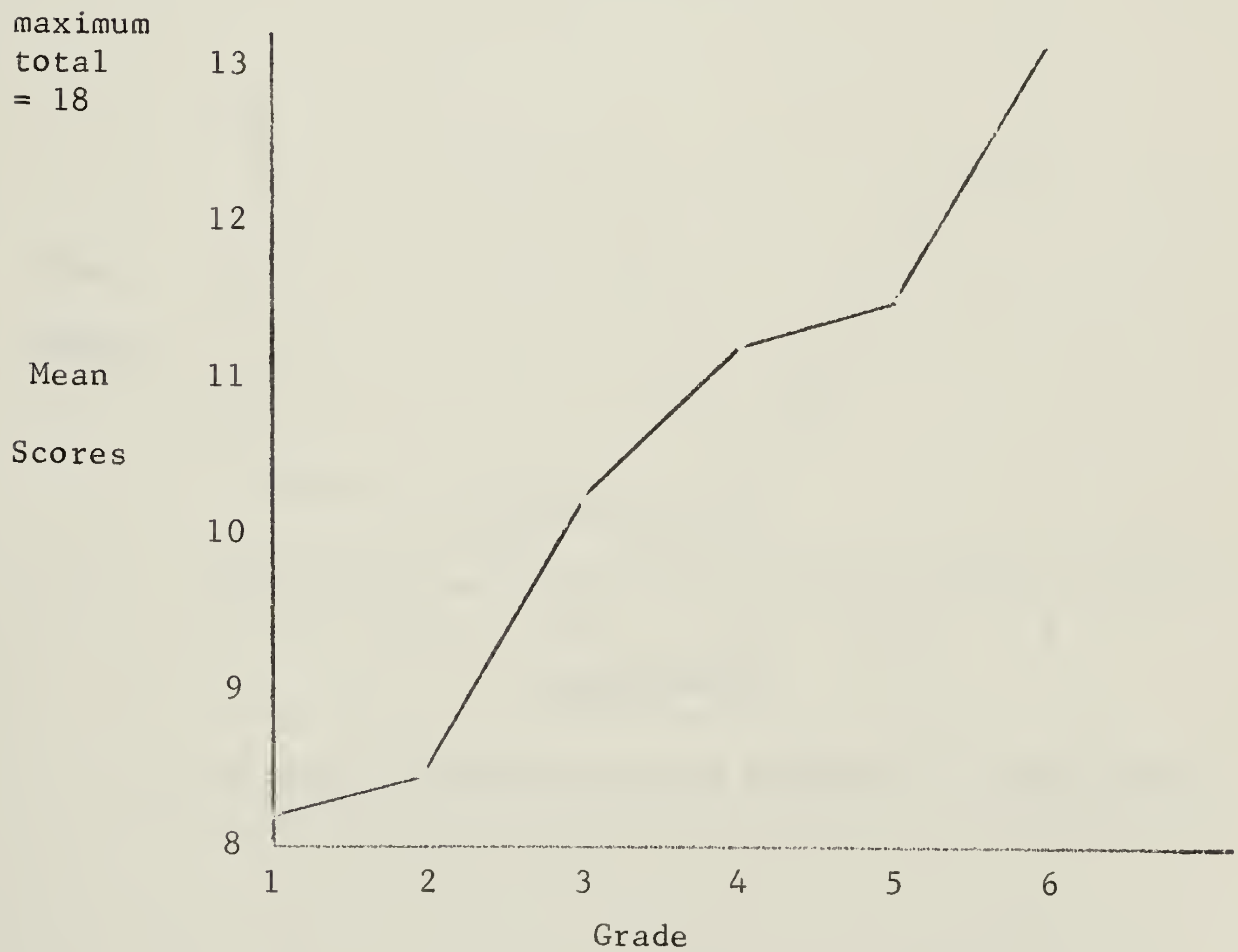

Figure 18. Mean Scores of Subtest III by Grade Level.

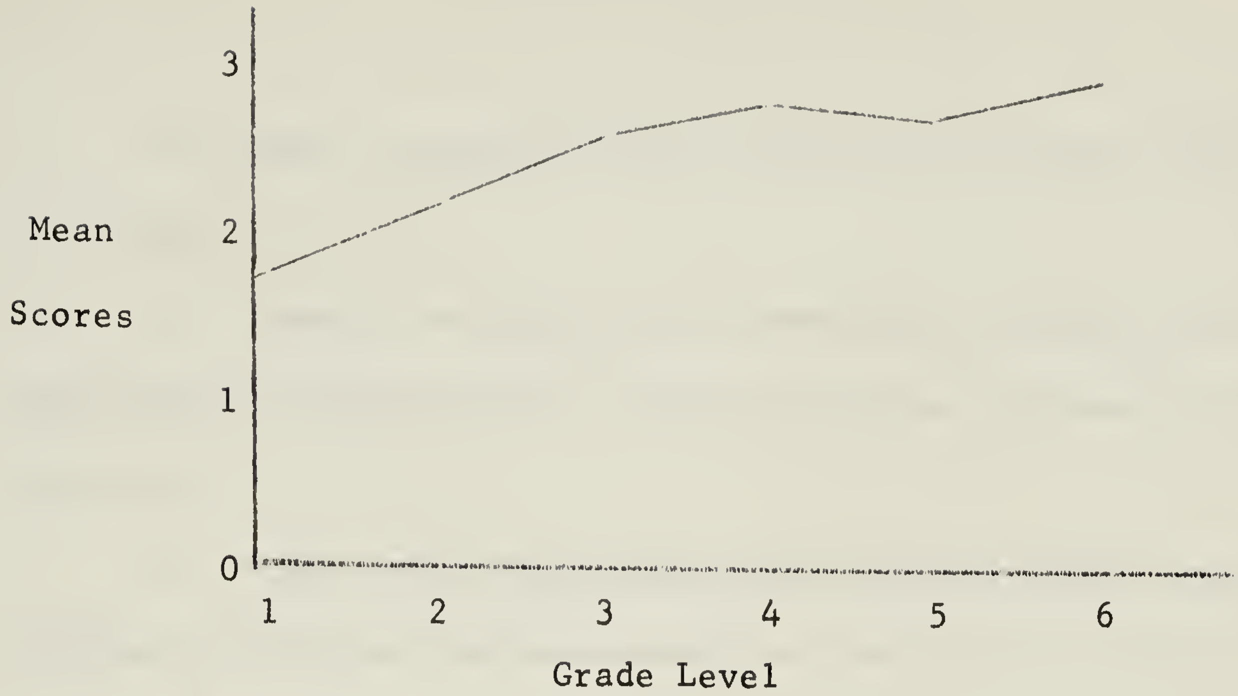

Figure 19. Mean Scores of Subtest IV by Grade Level.

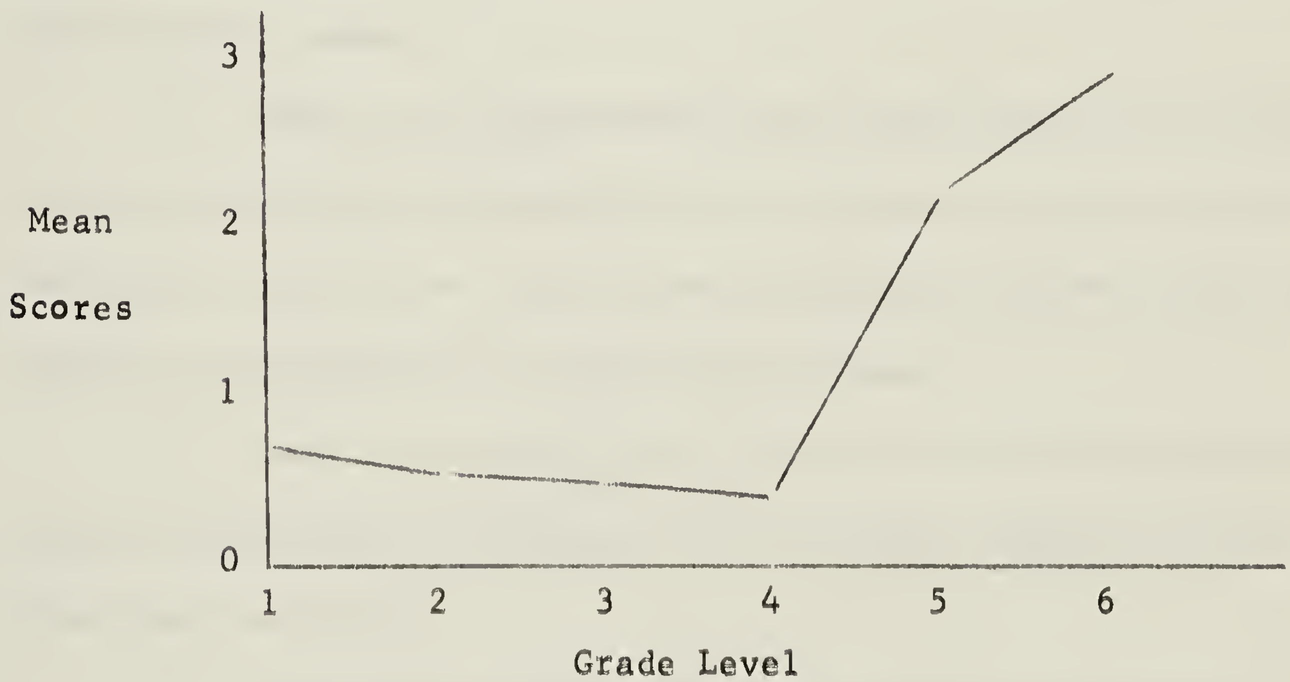

Figure 20. Mean Scores of Subtest V by Grade Level.

IV. SUMMARY OF FINDINGS

The major findings of this study may be briefly summarized as follows:

1. There is no significant correlation between sex and the development of concepts of a reference system, distance, direction, and scale.

2. There is no significant correlation between socio-economic status and the development of concepts of a reference system, distance, direction, and scale.

3. There is a significant correlation between chronological age and development of concepts of a reference system, distance, direction and scale.

4. There is a significant correlation between intelligence and the development of concepts of a reference system, direction and scale, but there is no significant correlation between intelligence and the development of a concept of distance.

5. There is a significant correlation between grade level and the development of concepts of a reference system, distance, direction, and scale.

6. Indications that children are aware of the need to align two spatial fields when copying a pattern from one to the other generally do not appear before a grade three level.

7. With the exception of the grade two children, most children were better able to organize a spatial field when provided

with some form of a coordinate axes system.

8. The four stages which were observed in the development of the concept of an artificial axes system are similar to those identified by Piaget in his experiments on the development of reference systems. However, the ages at which these stages appeared differed from those listed by Piaget. In general, the stages occurred later in this sample.

9. The methods used by this sample for judging distances were approximately the same as the methods noted by Piaget.

10. It was possible to identify the same stages of development of the concept of a natural axes system as outlined by Piaget. However, these stages appeared at much later ages than those listed by Piaget.

11. Observations of the testing situation confirmed the existence of the stages of development Piaget claims exist for the concept of scale. In this case the ages at which these stages occurred corresponded to those listed by Piaget.

CHAPTER V

SUMMARY, CONCLUSIONS, IMPLICATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

1. THE PURPOSE OF THE STUDY

The purpose of this study was to select four concepts which the investigator considered to be necessary to map reading and map interpretation and to examine their development in elementary school children.

The four concepts chosen for investigation were:

1. the concept of a reference system,
2. the concept of distance,
3. the concept of direction,
4. the concept of scale.

The development of these concepts was examined by means of administering a test, (A Test of Four Spatial Concepts), constructed by the investigator. This test was comprised of a battery of five subtests each of which was designed to measure the development of a certain concept. These subtests attempted to measure the development of a child's concept of:

1. a reference system utilizing an artificial coordinate axes system,

2. a reference system utilizing a natural coordinate axes system,
3. distance,
4. direction,
5. scale.

This battery of tests was administered by the investigator to a sample of 120 elementary school children selected at random from two schools in the public school system of Edmonton, Alberta, Canada. This sample consisted of ten males and ten females from each grade, one to six inclusive. Thus, there were an equal number of males and females for the sample as a whole and a total of twenty subjects from each grade level. The ages of these children ranged from six years seven months to twelve years seven months. The intelligence of the group as measured by the Lorge-Thorndike Intelligence test ranged from seventy-seven to one hundred and forty-three. When these children were classified according to socio-economic status according to the Blishen Occupational Class Scale, forty-seven were found to belong to the group identified as high socio-economic status and seventy-seven were classified as low socio-economic status.

The Test of Four Spatial Concepts was administered to each of these subjects in an individual testing situation. Every precaution was taken to assure that the administration of the test and the testing situation did not vary from one subject to another. The testing program was carried out during the last

two weeks of May and the first two weeks of June, 1965.

Although there may well be other concepts basic to a child's understanding and interpretation of maps, this study was confined to an investigation of four concepts only. The study was also limited in that it involved only a sample of urban pupils in grades one to six inclusive. No interpretation of the conclusions which follow should be made without an awareness of these limitations and the fact that the results of the study are based on a fundamental assumption, that is, that the test items were valid measures of the concepts under investigation and that a subject's performance on an item is indicative of his or her acquisition of the particular concept that item was designed to measure.

The test was scored and the results analyzed during the months of July and August 1965. The statistical analysis was carried out by means of an IBM computer through the Computing Services of the University of Alberta. In this analysis the following hypotheses were tested.

1. There is no significant correlation between sex and the development of a concept of a reference system, distance, direction, and scale.

2. There is no significant correlation between socio-economic status and the development of a concept of a reference system, distance, direction, and scale.

3. There is no significant correlation between chronological age and the development of a concept of a reference system, distance, direction, and scale.

4. There is no significant correlation between intelligence and the development of a concept of a reference system, distance, direction, and scale.

5. There is no significant correlation between grade level and the development of a concept of a reference system, distance, direction, and scale.

II. SUMMARY OF RESULTS AND CONCLUSIONS

On the basis of the findings of this study, the following conclusions may be drawn.

1. No significant correlation was found to exist between sex and the development of concepts of a reference system, distance, direction, and scale. The part of this finding which pertains to the concept of a reference system concurs with the findings of Rivoire (1962) who also found that sex did not have any effect on the formation of this concept.

2. No significant correlation was found to exist between socio-economic status in the sample tested and the development of concepts of a reference system, distance, direction, and scale. This finding does not substantiate Vinacke's claim that there is a connection between socio-economic status and concept formation. However, the method used to classify subjects in this study as to their social class membership may have tended to nullify any differences which did exist between the high and low groups.

3. There was a significant correlation between chronological age and the development of the concepts of a reference system, distance, direction, and scale. This finding is in agreement with that of Dodwell (1963) who concluded that an over-all ability to deal with spatial concepts increased with age. The results of this study indicate that an increase in age is accompanied by an increase in the development of these concepts. However, the exact nature of this relationship is not explicit, therefore, this conclusion should not be interpreted as meaning that an increase in the development if these spatial concepts will necessarily follow an increase in the subject's chronological age.

4. Intelligence for this sample was found to be significantly related to the development of concepts of a reference system, direction, and scale. The development of a concept of distance was not found to be significantly related to the intelligence of the subjects used in this study. In interpreting this conclusion it must be realized that the results of the test for the concept of distance were very low for the sample as a whole and that very few subjects appeared to have a fully developed concept of distance as measured by this test. In addition, the fact that none of the five items used in the subtest on distance were significantly correlated with each other would lead one to conclude that the children in this sample viewed each of these test items as being separate and different from the others. That is, it would appear that no one common factor was used by the subjects in visually estimating the five different distances.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

5. The relationship between the grade level of the subjects in the sample and the development of concepts of a reference system, distance, direction, and scale was found to be significant. The results indicate that the development of these spatial concepts increase as the grade level of the subject rises. However, since this developmental increase was shown to be linked with chronological age, and with one exception intelligence, it should be realized that no one of these factors may be said to account for the increase in its entirety.

6. Four stages in the development of the concept of a reference system utilizing an artificial axes were observed among the children tested. The characteristics of these stages matched those of the four stages described by Piaget (1963). However, these stages occurred at later ages than they did for Piaget's sample.

7. Three stages in the development of the concept of a reference system utilizing a natural axes system were observed among the sample of children tested. These stages and their characteristics were similar to the three stages Piaget (1963) describes for the development of a natural axes reference system. However, the ages at which these stages occurred were found to be much later than the ages Piaget lists for his sample.

This finding and the previous one both pertain to the formation of a concept of a general reference system. The finding that the ages at which the stages of development occur are later for this sample than for Piaget's concurs with the finding of Satterly (1964)

who also found the ages for the development of this concept to extend past those listed by Piaget.

8. Three stages in the development of the concept of direction were observed among the children in this sample. These stages appeared to be closely connected with the subject's ability to use objects as reference points and approximated the logical development of thought processes as outlined by Piaget(1963). Since the analysis of covariance indicated that when intelligence was held constant there were no significant differences between the subjects' mean scores from one grade to another, it would appear that intelligence and not maturational factors might well be the most important aspect in the development of this concept.

9. Three stages in the development of the concept of scale were observed among the children tested. These stages are similar to those found by Piaget (1963) in his experiments involving the concept of scale. For this sample, the ages at which these three stages occur is later than the ages Piaget found, but the general pattern of development is quite similar. This finding supports that of Sorohan (1963) who also found that the development of a concept of scale occurs later than Piaget claims.

III. IMPLICATIONS

The findings of this study give rise to several suggestions for educational practices.

1. Any program which is designed to be used in teaching map reading and map interpretation to elementary school children should clearly identify the spatial concepts which pertain to the development of these abilities. Furthermore, the authors of such a program should be cognizant of the level of conceptual development which would be characteristic of the children for which the program is intended.

2. Programs of this kind must attempt to foster the development of these concepts in an orderly and sequential manner in which the child's ability to comprehend and master the required concepts is taken into account.

3. In order to facilitate conceptual development and since it is recognized that concept formation is closely associated with experience, children should be provided with numerous opportunities to engage in situations structured to foster the development of certain concepts. Educators should also realize that while a child may normally reach a certain stage of conceptual development for a concept at a specified age, it does not necessarily follow that this concept could not have been developed earlier. Rather, it is quite possible and entirely probable that a child's development of certain concepts might be facilitated by special teaching to the point where these concepts might develop at a much earlier age than is normally the case at the present time.

4. In order to facilitate the development of the concept of a reference system school children beginning in grade one should be given experiences in which they are required to

express the location of one object or point relative to another object or point in terms of some form of a coordinate axes system. Large scale street maps of the childrens' own neighborhood could be utilized for this purpose. In such a case the streets and roads of the map would provide a coordinate axes system. Later, the use of the reference system provided by the numbers and letters on the margins of road maps could be introduced and explained. This concept of a reference system could then be sequentially expanded throughout the grades to the point where the largest of all coordinate axes systems, the earth's grid system of latitude and longitude could be introduced.

5. This study indicates that children appear to have great difficulty in visually estimating small distances. Since, this ability is necessary in map reading and map interpretation as well as mathematics, art, music, and other subjects, efforts should be made to develop a series of lessons which could be used to enable children to develop this ability more fully. One suggestion for such a series of lessons is that teachers might approach the problem by involving the children in direct experiences in which various distances would be compared and measured both visually and by means of a standard unit. Exercises of this nature might be developed involving distances on maps, in art, mathematics, music, and other school subjects.

6. A concept of direction is absolutely essential in any form of map reading and map interpretation and is necessary to some

degree for normal, every day living. In map work places are referred to in terms of their direction and distance from some established point. Similarly, in every day experiences children use a concept of direction to enable them to move about their own community. In doing the latter, children more or less unconsciously utilize objects as landmarks or reference points and move in a certain direction from them. When this procedure is transferred from the concrete to the abstract and the real world is transferred into a two-dimensional map, children and some adults appear to experience some difficulty in maintaining their sense of direction. However, there is no reason why lessons could not be designed for use in teaching pupils how to utilize reference points to avoid confusion of directions. Activities of this nature could be incorporated in almost any map study program. For instance, even at the grade one level if children were using a large scale street map of their community, they might be encouraged to express the directions for a certain route in terms of right or left (or the cardinal directions) and certain reference points. Thus, the directions for part of a route might be expressed as "you turn left (or west) walk two blocks and turn right (or north), etc."

7. According to the results of this study, children have relatively little awareness of the concept of scale until approximately the ages of ten or eleven. However, it is possible that through teaching, the development of this concept could be hastened. In order to do this children should be given opportunities to work with a variety of real objects of various scales and helped to discriminate between these scales.

8. The findings that some children visualize certain spatial configurations as reversed or as mirror images and that they are not aware of this alteration in their perceptions has important implications for the fields of reading, writing, art, mathematics, map study and any other area where a child is required to work with spatial configurations. Educators should be aware of the occurrence of this type of behaviour and some kind of test should be administered which would idenify those children who experience perceptual difficulties of this nature. When these children are identified, they should be given practice in recognizing the similarities and discrepancies among various spatial configurations.

9. Another suggestion for an activity which would involve the concepts of a reference system, distance, direction and possibly scale is that older elementary school children be given an opportunity to engage in instructional exercises of "orienteering". This is an outdoor activity in which children use a map and compass in conjunction with a set of directions which they attempt to follow. The object of the activity is to practice the correct use of this equipment as well as map reading and map interpretation skills in order to arrive at a predetermined destination. Activities of this nature would prove valuable in fostering the development of concepts of a reference system, distance and direction and could be developed to include the concept of scale.

The activities mentioned above are merely suggestions and teachers should be encouraged to experiment and design other activities which might help children develop these spatial concepts.

IV. SUGGESTIONS FOR FURTHER RESEARCH

This study has given rise to a number of suggestions which might be useful in conducting further research in this area. Some of these suggestions are presented below.

1. According to the findings of this study, children's concepts of distance are not well developed by the age of twelve years. Further research regarding concept development in this area might well be undertaken in an attempt to find what factors influence the development of this concept and exactly how it develops.

2. Since it has been shown that chronological age, intelligence and grade level are all significantly related to the development of certain spatial concepts, it might be profitable to conduct further research to determine the exact nature of these relationships.

3. In the case of many of the concepts investigated in this study the acquisition of a concept appeared suddenly and then developed rapidly. What factors affected this development and why did they act when they did?

4. Eye dominance, monocular vision, astigmatism and other visual factors may have an effect on the development of certain spatial concepts. Therefore, the relationship between visual acuity and the development of such concepts should be investigated.

5. Most map work is conducted using small scale representations of the real world. Can skills and concepts developed through the use of such materials be effectively applied to real-life situations? This is another area in which more research should be conducted.

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APPENDIX A

University of Alberta
Faculty of Education
May, 1965

Dear ______________________:

We are pleased to inform you that your child ______________________ has been chosen to participate in a project designed to improve the education of elementary school children. We are endeavouring to discover what thought processes children use when they work with maps, in order that additional research evidence may be brought to bear on the problem of designing learning materials suited to childrens' needs. By participating in this project, your child will contribute greatly to its success.

We should also like to assure you that this project has been approved by the Edmonton Public School Board and that the small amount of time required of your child will in no way interfere with his regular schooling. Rather, participation in this project may be regarded as an educational experience in itself.

The results of any tests administered will be held in strictest confidence and will in no way reflect learning ability or school potential. In any event, no child will be identified when the results of the study are published.

We hope that this letter will explain the activities your child will be engaged in, however, if you have further questions please feel free to contact us at the University (phone 439-8721, locals 743 or 663).

Sincerely,

J. O. Towler
M. L. Pedde

APPENDIX B

A TEST OF FOUR SPATIAL CONCEPTS

Subtest I. Artificial Axes

Apparatus: eight sheets of cardboard arranged in four pairs, the first of each pair with a pattern of markers fastened to it and the second sheet with no markers, thirteen round plastic markers, one of which has an axis marked on it are arranged as follows.

Pair 1.- no axis on either card.

Pair 2.- no axis on either card but one of the markers on the first card has an axis marked on it.

Pair 3.- a single orthogonal axis on each card.

Pair 4.- a nine sectioned grid system on both cards.

Section 1.- one card rotated and placed at an angle of 90^{o} relative to the second card.

1. (Pair 1.) Here is a sheet of cardboard with some markers on it. Can you place these markers on your sheet so that it will look exactly the same as mine? (Give subject all thirteen markers.)

2. (Pair 2.) Here is another card with markers on it. Can you make your card look exactly like this one?

3. (Pair 3.) Here is another card with markers. Try to make your card look like this one.

4. (Pair 4.) Here is one more card with markers on it. Can you make your card look exactly like this one.

Section 2.- cards placed parallel to each other. Present the pairs of cards in exactly the same order and manner as above. After both sections have been completed, ask the following questions.

1. Which way was it easiest to make your card look like mine, when the cards were like this, (rotated) or like this (parallel)? Why?

2. Which cards were easiest to copy? Why?

3. Could the lines on the cards have helped you place your markers? How?

Subtest II. Distance

Apparatus: five pairs of three-dimensional objects.

1. Here is a sheep and here is the shepherd who looks after him. Take a good look at the distance between them (examiner traces distance from one to the other with his finger) because I am going to give them to you in a minute and ask you to set them up the same distance apart. (Pick up both objects and hand them to the subject.) Now you set them up the same distance apart.

2. Here is a little lamb and here is the trough the farmer puts the lamb's food in. Take a good look at the distance between them. (Trace distance with finger, then hand them to subject.) Now you set them up the same distance apart.

3. Here are two horses. One is over here and the other is

over here. Look carefully at the distance between them. (Trace distance with finger and hand them to subject.) Now you set them up the same distance apart.

4. Here are two cows. One is lying down here and the other is over here. Look at the distance between them. (Trace distance and hand cows to subject.) Now you set them up the same distance apart.

5. Here are two men working in a field, one is here and the other is over here. Take a good look at the distance between them. (Trace the distance and hand the men to the subject.) Now you set them up the same distance apart.

Subtest III. Natural Axes

Apparatus: two identical three-dimensional models of a farm, complete with buildings and other objects, a screen placed between the models, nine pairs of identical objects. Here are two farms that are exactly the same. This one will be mine and that one will be yours. Now come over here (to one side of the screen) and watch what I do. I am going to place something on my farm and then I am going to give you the same thing to place on your farm. You must watch very carefully to see where I put it because when I give it to you, it must be put in exactly the same place on your farm. This is very important. You must put it in the same field and in the same place in the field as it is on my farm. Do you understand?

(From this point on, the subject should stand on one side

of the screen to watch the placing of an object and then step around the screen to place the object's counterpart on "his" farm. He should not be allowed to look back at the first model. After each pair of objects have been placed, they should be removed from both models.)

Section A - Second model rotated 90^{o}.

1. Here is a cow. I am going to place her here in this field. Take a good look at where she is. Here is your cow. Put her in the same place on your farm.

2. Here is the farm dog standing in this field. Take a good look at where he is. Here is your dog. Put him in exactly the same place on your farm.

3. Here is a little pig who got away from the others. Watch where I put him. Here is yours. Put him in the same place on your farm.

Section B - Second model rotated 180^{o}.

4. Here is a man carrying a pail. Look where I am putting him. Here is your man. Put him in the same place on your farm.

5. Here is a goat standing over here. Take a good look at where he is. Here is yours, put him in the same place on your farm.

6. Now here is a man who found a chicken. See, he has it in his arms. Watch where I am putting him. Here is your man. Put him in the same place on your farm.

Section C - Second model rotated 270^{o}.

7. Here is a woman throwing something out of a pail. I am

going to put her in this field. Take a good look at where she is. Here's your woman, put her in the same place on your farm.

8. Here is a man out working in this field. Watch where I am putting him. Here is your man, put him in the same place on your farm.

9. Here is a milk can ready to go to the dairy. Take a good look at where it is. Here is yours, put in the same place on your farm.

Subtest IV. Direction

Apparatus: two identical three-dimensional models of a crossroads and four fields, a screen between the models, and a toy truck.

Here are two models of some fields with roads running by them. Both models are exactly the same. Come over here (to side of the screen) and watch carefully what I am going to do on this model because I am going to ask you to do the same thing on the other model.

Look at this little red shed. This is where the farmer keeps his hay. Now one day the farmer had to take a bale of hay to town, so he took it out of the shed and put it in his truck. See, there is the hay in the truck. Now watch very carefully and see which way the farmer goes to drive to town. I am going to show you on this model and then you will have to drive him to town on the model over there. (Examiner "drives" truck down the road and makes a right turn at the crossroads. The second model should be turned 180^{o} while the child

is not watching. After he has performed the first task, it is useful to ask him to stand where he is and shut his eyes while the examiner turns the model as required. In this way the child's position does not change.)

1. (Model rotated 180^{o}) Here is the truck. Show me how the farmer gets to town on this model.

2. (Model rotated 90^{o}) Here is the truck again. Show me how he gets to town this time.

3. (Model rotated 270^{o}) Here is the truck. Show me how to get to town once more.

(After all three items have been completed, the following questions should be asked. In some cases the first reply will eliminate the necessity of asking them all.)

1. How did you know which way to go to town?
2. How did you know where to start?
3. How did you know which direction to turn when you got to the crossroads?

Subtest V. Scale

Apparatus: one large scale map of a farm and three-dimensional symbols, one "ground" for a second map, one-quarter the scale of the first, five cards each with five sizes of one symbol affixed to them.

Here is a model of a different farm. The farmer who lives here wanted to make a map of his farm. Now he had to change all the buildings for things that would lie flat so he let this (a

two-dimensional piece of cardboard cut to scale) stand for the barn, this for the shed, this for the chicken coop, this is the pond, and he let this stand for a granary. (In each case except for the pond, the two-dimensional object will have been fastened to the "ground" prior to the testing session. Then, when the three-dimensional object is removed, its two dimensional symbol will be revealed. In the case of the pond, since it already is a two-dimensional symbol, it need not be altered.)

When the farmer had finished making this map, he looked at it and decided he would like to have a smaller one. First he cut out this piece of cardboard (points to one-quarter scale card) and then he had to cut some shapes to stand for the buildings and the pond. Why couldn't he just use the same pieces of paper he used over there on the big map? Now it was very important that the farmer get the right size for the little map, so he cut five sizes for each of the things he was going to put on it. Here they are (point to the five cards). I want you to help the farmer choose the right size.

1. Here is the barn on this map (point to barn symbol on large map) and here are five barns on this card. Point to the one that you think is the correct size for the little map.

2. Here is the granary on this map (point to granary symbol on large map) and here are five granaries on this card. Point to the one that you think is the correct size for the little map.

3. Here is the shed on this map (point to shed symbol on large map) and here are five sheds on this card. Point to the one that you think is the correct size for the little map.

4. Here is the pond on this map (point to pond symbol on large map) and here are five ponds on this card. Point to the one that you think is the correct size for the little map.

5. Here is the chicken coop on this map (point to chicken coop symbol on large map) and here are five chicken coops on this card. Point to the one that you think is the correct size for the little map.

APPENDIX C

SCORE SHEET

Name ______________________ Grade ______________________

School ____________________ Sex ________________________

I.Q. ____________ C.A. ____________ Parent Occup. ________

Task I. Artificial Axes	Rotated	Parallel
1. no axis	______	______/8
2. chip axis	______	______/8
3. regular axis	______	______/8
4. grid system	______	______/8

Observations:

R1. ____

R2. ____

R3. ____

R4. ____

P1. ____

P2. ____

P3. ____

P4. ____

Task II. Distance

1. ______
2. ______
3. ______
4. ______
5. ______

Observations: ______________________________

____

Task III. Natural Axes

		S	Q
1.	Rotated 90^{o}		
	a) cow	______	______
	b) dog		
	c) pig		
2.	Rotated 180^{o}		
	a) pig feeder	______	______
	b) goat	______	______
	c) man and chick . . .	______	______
3.	Rotated 270^{o}		
	a) chicken feeder . . .	______	______
	b) man and fork	______	______
	c) milk can	______	______

Observations: ______________________________

____

Task IV. Direction

1. Rotated 180^{o} . . . . ______
2. Rotated 90^{o} . . . . ______
3. Rotated 270^{o} . . . . ______

Observations: ______________________________

____

Task V. Scale

A.	1.	2.	3.	4.	5.	Barn
B.	1.	2.	3.	4.	5.	Silo
C.	1.	2.	3.	4.	5.	Shed
D.	1.	2.	3.	4.	5.	Pond
E.	1.	2.	3.	4.	5.	Coop

Observations: ______________________________

____